

## CERAMIC DECAL ASSEMBLY

### Cross-reference to related patent application

This application is a continuation-in-part of co-pending patent application 10/621,976, filed on July 17, 2003, which is a continuation-in-part of co-pending patent application 10/265,013, filed on October 4, 2002, which is a continuation-in-part of co-pending patent application 10/080,783, filed on February 22, 2002, which is a continuation-in-part of patent application 09/961,493, filed on September 22, 2001, now United States Patent 6,629,792, issued on October 7, 2003, which in turn is a continuation-in-part of patent application 09/702,415, filed on October 31, 2000, now United States Patent 6,481,353, issued on November 19, 2002.

### Field of the invention

A ceramic decal assembly containing a ceramic substrate, a layer of adhesive contiguous with the substrate, and a ceramic decal contiguous with the layer of adhesive.

### Background of the invention

Glass and ceramic articles may be decorated or imaged with printed decals. Such decals are typically comprised of flexible substrates and thin transferable coatings or film. The desired image or decoration is first printed upon the transferable coating or film side of the decal. The image or decoration is then transferred to the ceramic or glass article along with the transferable coating or film it is printed upon. The ceramic or glass article is then fired to permanently affix the image or decoration to the glass or ceramic article.

Image transfer from the decal to the glass or ceramic article may be accomplished by first removing the flexible substrate from the imaged transfer layer or film and then placing it on the article in the desired location. Such a process may be facilitated by using a water slide decal which contains a thin water soluble layer between the flexible substrate and the transfer layer. By soaking such a decal in water, the imaged transfer layer is easily separated from the flexible substrate and placed on the article to be decorated.

Decals incorporating a heat-meltable layer may be used to thermally transfer the image from the decal to the article. In this thermal transfer process the imaged transfer layer is easily separated from the flexible substrate at elevated temperatures and transferred either directly or indirectly to the article to be decorated or imaged. During the heat transfer step, the image and transfer layer are never unsupported as is the case in the water slide process.

The applicants have discovered that pressure sensitive adhesives may be used to facilitate the transfer of the imaged transfer layer from the decal to the article to be decorated or imaged. This new process eliminates the need for a heat-meltable layer in the decal and enables the process to be conducted under ambient temperature conditions. Like the heat transfer process, the imaged transfer layer is never unsupported in the pressure sensitive adhesive transfer process. However, in this adhesive transfer process, direct transfer of the imaged transfer layer to the article is preferred.

Processes for preparing "decals" are well known. Thus, e.g., in United States patent 5,132,165 of Louis A. Blanco, a wet printing technique was described comprising the step of offset printing a first flux layer onto a backing sheet, forming a wet ink

formulation free of glass and including a liquid printing vehicle and oxide coloring agent, wet printing the wet ink formulation onto the first flux layer to form a design layer, and depositing a second flux layer onto the design layer.

The process described by this Blanco patent is not readily adaptable to processes involving digital imaging, for the wet inks of this patent are generally too viscous for ink jet printing and not suitably thermoplastic for thermal transfer or electrophotographic printing.

Digital printing methodologies offer a more convenient and lower cost method of mass customization of ceramic articles than do conventional analog printing methodologies, but they cannot be effectively utilized by the process of the Blanco patent.

The Blanco patent issued in July of 1992. In September of 1997, United States patent 5,665,472 issued to Konsuke Tanaka. This patent described a dry printing process that overcame some of the disadvantages of the Blanco process. The ink formulations described in the Tanaka patent are dry and are suitable to processes involving digital imaging.

However, although the Tanaka process is an improvement over the Blanco process, it still suffers from several major disadvantages, which are described below.

The Tanaka patent discloses a thermal transfer sheet which allegedly can "...cope with color printing...." According to Tanaka, "...thermal transfer sheets for multi-color printing also fall within the scope of the invention" (see Column 4, lines 64-67). However, applicants have discovered that, when the Tanaka process is used to prepare

digitally printed backing sheets for multi-coloring printing on ceramic substrates, unacceptable results are obtained.

The Tanaka process requires the presence of two "essential components" in a specified glass frit (see lines 4-12 of Column 4). According to claim 1 of United States patent 5,665,472, the specified glass frit consists essentially of 75 to 85 weight percent of Bi<sub>2</sub>O<sub>3</sub> and 12 to 18 weight percent of B<sub>2</sub>O<sub>3</sub>, which are taught to be the "essential components" referred to by Tanaka. In the system of this patent, the glass frit and colorant particles are dispersed in the same ink. It is taught that, in order to obtain good dispersibility in this ink formulation, the average particle size of the dispersed particles should be from about 0.1 to about 10 microns (see Column 4 of the patent, at lines 13-17).

In the example presented in the Tanaka patent (at Column 7 thereof), a temperature of 450 degrees Celsius was used to fire images printed directly from thermal transfer sheets made in accordance with the Tanaka process to a label comprised of inorganic fiber cloth coated with some unspecified ceramic material.

When one attempts to use the process of the Tanaka patent to transfer images from a backing sheet to solid ceramic substrates (such as glass, porcelain, ceramic whitewares, etc.), one must use a temperature in excess of 550 degrees Celsius to effectively transfer an image which is durable. However, when such a transfer temperature is used with the Tanaka process, a poor image comprised with a multiplicity of surface imperfections (such as bubbles, cracks, voids, etc.) is formed. Furthermore, when the Tanaka process is used to attempt to transfer color images, a poor image with low color density and poor durability is formed. The Tanaka process, although it may be

useful for printing on flexible ceramic substrates such as glass cloth, is not useful for printing images on most solid ceramic substrates.

It is an object of this invention to provide a ceramic decal assembly which, after being fired, produces durable images on a ceramic substrate, wherein the optical quality of the fired images is substantially as good as that of the unfired images.

Summary of the invention

In accordance with this invention, there is provided a ceramic decal assembly containing a ceramic substrate, a layer of adhesive contiguous with the substrate, and a ceramic decal contiguous with the layer of adhesive.

Brief description of the drawings

The invention will be described by reference to this specification and the attached drawings, in which like numerals refer to like elements, and in which:

Figure 1 is a schematic representation of a ceramic substrate to which a color image has been transferred in accordance with the invention;

Each of Figures 2, 3, 4, 5, and 6 is a schematic of a preferred ribbon, which may be used to prepare the ceramic substrate of Figure 1;

Figure 6A is a schematic representation of another preferred ribbon which may be used to prepare the ceramic substrate of Figure 1; Each of Figures 7 and 8 is schematic of a preferred decal which may be used to prepare the ceramic substrate of Figure 1;

Each of Figures 9, 10, 10A, and 11 is a flow diagram illustrating how the ribbon, a first decal, a second decal, and the printed ceramic substrate of the invention, respectively, is made;

Figure 12 is a schematic representation of a thermal ribbon comprised of a frosting ink layer;

Figures 13, 13A, and 13B are schematic representations other thermal ribbons comprised of a frosting ink layer;

Figure 14 is a schematic representation of a heat transfer paper made with the thermal ribbon of Figure 12 or Figure 13;

Figure 15 is a schematic representation of a Waterslide paper assembly made with the thermal ribbon of Figure 12 or Figures 13, 13A, or 13B;

Figure 16 is a schematic representation of a transferable covercoat paper assembly;

Figure 17 is a flow diagram illustrating a process for making a frosting image decal with either the heat transfer paper of Figure 14, the Waterslide paper assembly of Figure 15, or the transferable covercoat assembly of Figure 16;

Figure 18 is a flow diagram/logic diagram describing how one may transfer the frosting image decal of Figure 17 to a ceramic substrate;

Figure 19 is a schematic representation of ceramic or glass substrate on which is disposed a frosting ink image and two covercoat layers;

Figure 20 is a schematic representation of a flexible substrate on which is disposed a frosting ink image;

Figure 21 is a schematic representation of a ceramic or glass substrate on which is disposed the flexible substrate of Figure 20;

Figure 22 is a schematic representation of a laminated structure in which the flexible substrate assembly of Figure 20 is disposed between two ceramic or glass layers;

Figure 23 is a schematic representation of a ceramic or glass substrate beneath which is disposed a frosting ink image;

Figure 24 is a flow diagram of one preferred process of the invention for pressure sensitive adhesive transfer of ceramic decals to glass or ceramic substrates;

Figures 25A and 25B are schematics of two preferred decals which may be used in the process depicted in Figure 24;

Figure 26 is a schematic of a preferred adhesive assembly, which may be used in the process depicted in Figure 24;

Figure 27 is a schematic of one preferred lamination step of the process depicted in Figure 24;

Figure 28 is a schematic of one preferred stripping step of the process depicted in Figure 24 in which release paper is stripped away from pressure sensitive adhesive;

Figure 29 is a schematic of one preferred lamination step of the process depicted in Figure 24 in which the decal is laminated to a glass or ceramic substrate with pressure;

Figure 30 is a schematic of one preferred stripping step of the process depicted in Figure 24 in which a paper/wax resin release layer is stripped away to leave a covercoated image on the glass or ceramic substrate;

Figure 31 is a schematic of the assembly containing the covercoated image on the glass or ceramic substrate; and

Figure 32 is a schematic of a process of evaluating the optical properties of the glass/ceramic substrate with an image fixed to it.

Figure 33 is a flow diagram of another preferred process of the invention for pressure sensitive adhesive transfer of ceramic decals to glass or ceramic substrates;

Figure 34 is a schematic of a preferred adhesive assembly, which may be used in the process depicted in Figure 33;

Figure 35 is a schematic of one preferred lamination step and two preferred stripping steps of the process depicted in Figure 33 in which the one adhesive release liner is stripped away from the pressure sensitive transfer adhesive, the adhesive is pressure laminated to a glass or ceramic substrate and then the second adhesive release liner is stripped away from the adhesive;

Figure 36 is a schematic of one preferred lamination step and one preferred stripping step of the process depicted in Figure 33 in which the imaged decal is pressure laminated to a glass or ceramic substrate and then the flexible decal substrate is stripped away.

Figure 37 is a schematic representation of one imaged covercoat.

Figure 38 is a schematic representation of a ceramic decal assembly employing a flexible covercoat.

Figure 39 is a schematic representation of another ceramic decal assembly employing a flexible covercoat.

Figure 40 is a schematic depicting the peeling of a flexible covercoat from a frosting ink image.

#### Description of the preferred embodiments

In the first part of this specification, a novel thermal transfer system for fired ceramic decals will be discussed. Thereafter, in the second part of the specification, a novel thermal transfer ribbon comprised of a frosting ink will be discussed. In the third

part of this specification, a process for preparing a ceramic substrate/adhesive/decal assembly will be described.

Figure 1 is a schematic representation of a printed ceramic substrate 10 made in accordance with one preferred process of this invention. The Figures of this patent application are not necessarily drawn to scale.

Printed ceramic substrate 10 is comprised of a ceramic substrate 12 onto which the color image(s) is fixed.

The ceramic substrate used in the process of this invention preferentially has a melting temperature of at least 550 degrees Celsius. As used in this specification, the term melting temperature refers to the temperature or range of temperatures at which heterogeneous mixtures, such as a glass batch, glazes, and porcelain enamels, become molten or softened. See, e.g., page 165 of Loran S. O'Bannon's "Dictionary of Ceramic Science and Engineering" (Plenum Press, New York, 1984). In one embodiment, it is preferred that the substrate have a melting temperature of at least about 580 degrees Celsius. In another embodiment, such melting temperature is from about 580 to about 1,200 degrees Celsius.

The ceramic substrate used in the process of this invention preferably is a material which is subjected to a temperature of at least about 540 degrees Celsius during processing and is comprised of one or more metal oxides. Typical of such preferred ceramic substrates are, e.g., glass, ceramic whitewares, enamels, porcelains, etc. Thus, byway of illustration and not limitation, one may use the process of this invention to transfer and fix images onto ceramic substrates such as dinnerware, outdoor signage, glassware, decorative giftware, architectural tiles, color filter arrays, floor tiles, wall tiles,

perfume bottles, wine bottles, beverage containers, glass windows, doors and partitions and the like.

Referring again to Figure 1, and in the preferred but optional embodiment depicted therein, it will be seen that a flux underlayer 14 is disposed on top of and bonded to the top surface of the ceramic substrate 12. Flux underlayer 14 is preferably transferred to the ceramic substrate surface at a coating weight (coverage) of at least about 1 gram per square meter. It is preferred to use a coating weight (coverage) for flux layer 14 of at least 7 grams per square meter; and it is more preferred to use a coating weight (coverage) for layer 14 of at least about 14 grams per square meter. As will be apparent to those skilled in the art, the coating weight (coverage) referred to herein (and elsewhere in this specification) is a dry weight, by weight of components which contain less than 1 percent of solvent.

The coating composition used to apply layer 14 onto ceramic substrate 12 must contain frit with a melting temperature of at least about 550 degrees Celsius. As used in this specification, the term frit refers to a glass which has been melted and quenched in water or air to form small friable particles which then are processed for milling for use as the major constituent of porcelain enamels, fritted glazes, frit chinaware, and the like. See, e.g., page 111 of Loran S. O'Bannon's "Dictionary of Ceramic Science and Engineering," supra.

In one embodiment, the frit used in the process of this invention has a melting temperature of at least about 750 degrees Celsius. In another embodiment, the frit used in the process of this invention has a melting temperature of at least about 950 degrees Celsius.

One may use commercially available frits. Thus, by way of illustration and not limitation, one may use a frit sold by the Johnson Matthey Ceramics Inc. (498 Acorn Lane, Downingtown, Pa. 19335) as product number 94C1001 ("Onglaze Unleaded Flux"), 23901 ("Unleaded Glass Enamel Flux,"), and the like. One may use a flux sold by the Cerdec Corporation of P.O. Box 519, Washington, Pa. 15301 as product number 9630.

Applicants have discovered that, for optimum results, the melting temperature of the frit used should be either substantially the same as or no more than 50 degrees lower than the melting point of the substrate to which the colored image is to be affixed.

The frit used in the coating composition, before it is melted onto the substrate by the heat treatment process described elsewhere in this specification, preferably has a particle size distribution such that substantially all of the particles are smaller than about 10 microns. In one embodiment, at least about 80 weight percent of the particles are smaller than 5.0 microns.

One may use many of the frits known to those skilled in the art such as, e.g., those described in United States patents 5,562,748, 5,476,894, 5,132,165, 3,956,558, 3,898,362, and the like. Similarly, one may use some of the frits disclosed on pages 70-79 of Richard R. Eppler et al.'s "Glazes and Glass Coatings" (The American Ceramic Society, Westerville, Ohio, 2000).

Referring again to Figure 1, the flux underlayer 14 preferably is comprised of at least about 25 weight percent of one or more frits, by total dry weight of all components in layer 14. In one embodiment, from about 35 to about 85 weight percent of frit material is used in flux underlayer 14. In another embodiment, from about 65 to about 75 percent of such frit material is used.

It is preferred that the frit material used in layer 14 comprise at least about 5 weight percent, by dry weight, of silica. As used herein, the term silica is included within the meaning of the term metal oxide; and the preferred frits used in the process of this invention comprise at least about 98 weight percent of one or more metal oxides selected from the group consisting of lithium, sodium, potassium, calcium, magnesium, strontium, barium, zinc, boron, aluminum, silicon, zirconium, lead, cadmium, titanium, and the like.

Referring again to Figure 1, in addition to the frit, layer 14 also is comprised of one or more thermoplastic binder materials in a concentration of from about 0 to about 75 percent, based upon the dry weight of frit and binder in such layer 14. In one embodiment, the binder is present in a concentration of from about 15 to about 35 percent. In another embodiment, the layer 14 is comprised of from about 15 to about 75 weight percent of binder.

One may use any of the thermal transfer binders known to those skilled in the art. Thus, e.g., one may use one or more of the thermal transfer binders disclosed in United States patent 6,127,316, 6,124,239, 6,114,088, 6,113,725, 6,083,610, 6,031,556, 6,031,021, 6,013,409, 6,008,157, 5,985,076, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

By way of further illustration, one may use a binder which preferably has a softening point from about 45 to about 150 degrees Celsius and a multiplicity of polar moieties such as, e.g., carboxyl groups, hydroxyl groups, chloride groups, carboxylic acid groups, urethane groups, amide groups, amine groups, urea, epoxy resins, and the like. Some suitable binders within this class of binders include polyester resins, bisphenol-A polyesters, polvinyl chloride, copolymers made from terephthalic acid, polymethyl

methacrylate, vinyl chloride/vinyl acetate resins, epoxy resins, nylon resins, urethane-formaldehyde resins, polyurethane, mixtures thereof, and the like.

In one embodiment a mixture of two synthetic resins is used. Thus, e.g., one may use a mixture comprising from about 40 to about 60 weight percent of polymethyl methacrylate and from about 40 to about 60 weight percent of vinylchloride/vinylacetate resin. In this embodiment, these materials collectively comprise the binder.

In one embodiment, the binder is comprised of polybutylmethacrylate and polymethylmethacrylate, comprising from 10 to 30 percent of polybutylmethacrylate and from 50 to 80 percent of the polymethylacrylate. In one embodiment, this binder also is comprised of cellulose acetate propionate, ethylenevinylacetate, vinyl chloride/vinyl acetate, urethanes, etc.

One may obtain these binders from many different commercial sources. Thus, e.g., some of them may be purchased from Dianal America of 9675 Bayport Blvd., Pasadena, Texas 77507; suitable binders available from this source include "Dianal BR 113" and "Dianal BR 106." Similarly, suitable binders may also be obtained from the Eastman Chemicals Company (Tennessee Eastman Division, Box 511, Kingsport, Tennessee).

Referring again to Figure 1, in addition to the frit and the binder, the layer 14 may optionally contain from about 0 to about 75 weight of wax and, preferably, 5 to about 20 percent of such wax. In one embodiment, layer 14 is comprised of from about 5 to about 10 weight percent of such wax. Suitable waxes which maybe used include carnuaba wax, rice wax, beeswax, candelilla wax, montan wax, paraffin wax, microcrystalline waxes, synthetic waxes such as oxidized wax, ester wax, low molecular weight polyethylene

wax, Fischer Tropsch wax, and the like. These and other waxes are well known to those skilled in the art and are described, e.g., in United States patent 5,776,280. One may also use ethoxylated high molecular weight alcohols, long chain high molecular weight linear alcohols, copolymers of alpha olefin and maleic anhydride, polyethylene, polypropylene,

These and other suitable waxes are commercially available from, e.g., the BakerHughes Baker Petrolite Company of 12645 West Airport Blvd., Sugarland, Texas.

In one preferred embodiment, carnuaba wax is used as the wax. As is known to those skilled in the art, carnuaba wax is a hard, high-melting lustrous wax which is composed largely of ceryl palmitate; see, e.g., pages 151-152 of George S. Brady et al.'s "Material's Handbook," Thirteenth Edition (McGraw-Hill Inc., New York, New York, 1991). Reference also may be had, e.g., to United States patents 6,024,950, 5,891,476, 5,665,462, 5,569,347, 5,536,627, 5,389,129, 4,873,078, 4,536,218, 4,497,851, 4,610,490, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

Layer 14 may also be comprised of from about 0 to 16 weight percent of plasticizers adapted to plasticize the resin used. Those skilled in the art are aware of which plasticizers are suitable for softening any particular resin. In one embodiment, there is used from about 1 to about 15 weight percent, by dry weight, of a plasticizing agent. Thus, by way of illustration and not limitation, one may use one or more of the plasticizers disclosed in United States patent 5,776,280 including, e.g., adipic acid esters, phthalic acid esters, chlorinated biphenyls, citrates, epoxides, glycerols, glycol, hydrocarbons, chlorinated hydrocarbons, phosphates, esters of phthalic acid such as, e.g., di-2-ethylhexylphthalate, phthalic acid esters, polyethylene glycols, esters of citric acid,

epoxides, adipic acid esters, and the like. In one embodiment, layer 14 is comprised of from about 6 to about 12 weight percent of the plasticizer which, in one embodiment, is dioctyl phthalate. The use of this plasticizing agent is well known and is described, e.g., in United States patents 6,121,356, 6,117,572, 6,086,700, 6,060,234, 6,051,171, 6,051,097, 6,045,646, and the like. The entire disclosure of each of these United States patent applications is hereby incorporated by reference into this specification. Suitable plasticizers may be obtained from, e.g., the Eastman Chemical Company.

Referring again to Figure 1, and in the preferred embodiment depicted therein, it will be seen that, disposed over flux layer 14, is opacification layer 16. Opacification layer 16 is optional; but, when it is used, it is preferably used at a coating weight (coverage) of from about 0.5 to about 10 grams per square meter and, more preferably, from about 1 to about 5 grams per square meter.

As is known to those skilled in the art, the opacification layer functions to introduce whiteness or opacity into the substrate by utilizing a substance that disperses in the coating as discrete particles which scatter and reflect some of the incident light. In one embodiment, the opacifying agent is used on a transparent ceramic substrate (such as glass) to improve image contrast properties.

One may use opacifying agents which were known to work with ceramic substrates. Thus, e.g., one may use one or more of the agents disclosed in United States patents 6,022,819, 4,977,013 (titanium dioxide), 4,895,516 (zirconium, tin oxide, and titanium dioxide), 3,899,346, and the like. The disclosure of each of these United States patents is hereby incorporated by reference into this specification. One may obtain

opacifying agents obtained from, e.g., Johnson Matthey Ceramic Inc., *supra*, as, e.g., "Superpax Zirconium Opacifier."

The opacification agent used should have a melting temperature at least about 50 degrees Celsius higher than the melting point of the frit(s) used in layer 14. Generally, the opacification agent(s) have a melting temperature greater than 600 degrees Celsius and preferably at least about 1200 degrees Celsius.

The opacification agent should have a refractive index greater than that of the glass frit. The opacification agent should have a refractive index greater than 1.5, preferably greater than 2.0 and, more preferably, greater than 2.4.

The opacification agent preferably has a particle size distribution such that substantially all of the particles are smaller than about 10 microns. In one embodiment, at least about 80 weight percent of the particles are smaller than 5.0 microns.

Referring again to Figure 1, in addition to the opacification agent, opacification layer 16 also is comprised of one or more thermoplastic binder materials in a concentration of from about 0 to about 75 percent, based upon the dry weight of opacification agent and binder in such layer 14. In one embodiment, the binder is present in a concentration of from about 15 to about 35 percent. One may use one or more of the binders described with reference to layer 14. Alternatively, one may use one or more other suitable binders.

In addition to the opacifying agent and the optional binder, one may also utilize the types and amounts of wax that are described with reference to layer 14, and/or different amounts of different waxes. Alternatively, or additionally, one may also use the types and amounts of plasticizer described with reference to layer 14. In general, the

only substantive differences between layers 14 and 16 are that the calculations are made with respect to the amount of opacifying agent (in layer 16) and not the amount of frit (as is done in layer 14). Referring again to Figure 1, one may optionally use a second flux layer i8 similar in composition and/or concentrations to layer 14. When such a second flux layer is used, it will be disposed over and printed over the opacification layer 16.

Disposed over the flux layer 14 is one or more color images 20. These ceramic colorant image(s) 20 will be disposed over either the ceramic substrate 12 or the flux layer 14, and/or the optional opacification layer 16 when used, and/or the optional second flux layer 18 when used.

It is preferred to apply these color image(s) with a digital thermal transfer printer. Such printers are well known to those skilled in the art and are described in International Publication No. WO 97/00781, published on January 7, 1997, the entire disclosure of which is hereby incorporated by reference into this specification. As is disclosed in this publication, a thermal transfer printer is a machine, which creates an image by melting ink from a film ribbon and transferring it at selective locations onto a receiving material. Such a printer normally comprises a print head including a plurality of heating elements, which may be arranged in a line. The heating elements can be operated selectively.

Alternatively, one may use one or more of the thermal transfer printers disclosed in United States patents 6,124,944, 6,118,467, 6,116,709, 6,103,389, 6,102,534, 6,084,623, 6,083,872, 6,082,912, 6,078,346, and the like. The disclosure of each of these United States patents is hereby incorporated by reference into this specification.

Digital thermal transfer printers are readily commercially available. Thus, e.g., one may use a printer identified as Gerber Scientific's Edge 2 sold by the Gerber

Scientific Corporation of Connecticut. With such a printer, the digital color image(s) may be applied by one or more appropriate ribbon(s) in the manner discussed elsewhere in this specification. Referring again to Figure 1, the colorant, or colorants which form image 20 are mixed with one or more of the ingredients listed for the opacification layer, with the exception that the colorant(s) is substituted for the opacifying agent(s). Thus, a mixture of the colorant and/or binder and/or wax and/or plasticizer may be used. As will be apparent to those skilled in the art, no glass frit is used in colorant image 20.

It is this element 20, which is selectively applied by the color printer. One such mixture, comprised of one color, may first be digitally printed, optionally followed by one or more differently colored mixtures. The number of colors one wishes to obtain in element 20 will dictate how many different colors are printed.

Although not willing to be bound to any particular theory, applicants believe that the colorant mixtures applied as element 20 tend to admix to some degree.

The amount of colorant used in the composite 11 should not exceed a certain percentage of the total amount of flux used in such composite, generally being 33.33 percent or less. Put another way, the ratio of the total amount of flux in the composite 11 (which includes layers 14, 18, and 24) to the amount of colorant in element 20, in grams/grams, dry weight, should be at least about 2 and, preferably, should be at least about 3. In one embodiment, such ratio is at least 4.0 In another such embodiment, such ratio of flux/colorant is from about 5 to 6. It is noteworthy that, in the process described in United States patent 5,665,472, such ratio was 0.66 (Example 1 at Column 5), or 0.89 (Example 2 at Columns 5-6), or 1.1 (Example 3 at Column 6). At Column 4 of United States patent 5,665,472 (see lines 44 to 49), the patentee teaches that "The proportion of

the weight of the bismuth oxide/borosilicate glass frit to the weight of the colorant is preferably 50 to 200 %...." Thus, substantially more colorant as a function of the flux concentration is used in the process of such patent than is used in applicants' process.

In another embodiment of the invention, the ratio of frit used in the process to colorant used in the process is at least 1.25.

The unexpected results, which obtain when the flux/colorant ratios of this invention are substituted for the flux/colorant ratios of the Tanaka patent, and when the flux and colorant layers are separated, are dramatic. A substantially more durable product is produced by the process of the instant invention.

Furthermore, applicants have discovered that, despite the use of substantial amounts of colorant, the process described in United States patent 5,665,472 does not produce transferred images with good color density. Without wishing to be bound to any particular theory, applicants believe that there is a certain optimal amount of encapsulation and immobilization of colorant and/or dissolution of colorant within the flux which is impeded by high concentrations of colorant.

It is disclosed in United States patent 5,665,472 that "The thermal transfer sheet of the present invention can, of course, cope with color treatment," and this statement is technically true. However, such process does not cope very well and must be modified in accordance with applicants' unexpected discoveries to produce a suitable digitally printed backing sheet with adequate durability and color intensity.

The only colorant disclosed in United States patent 5,665,472 is a fired pigment comprised of ferric oxide, cobalt oxide, and chromium trioxide in what appears to be a spinel structure. It is not disclosed where this pigment is obtained from, or what

properties it has. The colorants which work well in applicants' process preferably each contain at least one metal-oxide. Thus, a blue colorant can contain the oxides of a cobalt, chromium, aluminum, copper, manganese, zinc, etc. Thus, e.g., a yellow colorant can contain the oxides of one or more of lead, antimony, zinc, titanium, vanadium, gold, and the like. Thus, e.g., a red colorant can contain the oxides of one or more of chromium, iron (two valence state), zinc, gold, cadmium, selenium, or copper. Thus, e.g., a black colorant can contain the oxides of the metals of copper, chromium, cobalt, iron (plus two valence), nickel, manganese, and the like. Furthermore, in general, one may use colorants comprised off the oxides of calcium, cadmium, zinc, aluminum, silicon, etc.

Suitable colorants are well known to those skilled in the art. See, e.g., United States patents 6,120,637, 6,108,456, 6,106,910, 6,103,389, 6,083,872, 6,077,594, 6,075,927, 6,057,028, 6,040,269, 6,040,267, 6,031,021, 6,004,718, 5,977,263, and the like. The disclosure of each of these United States patents is hereby incorporated by reference into this specification.

By way of further illustration, some of the colorants which can be used in the process of this invention include those described in United States patents 6,086,846, 6,077,797 (a mixture of chromium oxide and blue cobalt spinal), 6,075,223 (oxides of transition elements or compounds of oxides of transition elements), 6,045,859 (pink coloring element) 5,988,968 (chromium oxide, ferric oxide), 5,968,856 (glass coloring oxides such as titania, cesium oxide, ferric oxide, and mixtures thereof), 5,962,152 (green chromium oxides), 5,912,064, 5,897,885, 5,895,511, 5,820,991 (coloring agents for ceramic paint), 5,702,520 (a mixture of metal oxides adjusted to achieve a particular color), and the like. The entire disclosure of each of these United States patents is hereby

incorporated by reference into this specification. The ribbons produced by the process of this invention are preferably leach-proof and will not leach toxic metal oxide. This is unlike the prior art ribbons described by Tanaka at Column 1 of United States patent 5,665,472, wherein he states that: "In the case of the thermal transfer sheet containing a glass frit in the binder of the hot-melt ink layer, lead glass has been used as the glass frit, posing a problem that lead becomes a toxic, water-soluble compound." Without wishing to be bound to any particular theory, applicants believe that this undesirable leaching effect occurs because the prior art combined the flux and colorant into a single layer, thereby not leaving enough room in the formulation for sufficient binder to protect the layer from leaching.

The particle size distribution of the colorant used in layer 20 should preferably be within a relatively narrow range. It is preferred that the colorant have a particle size distribution such that at least about 90 weight percent of its particles are within the range of 0.2 to 20 microns.

The colorant used preferably has a refractive index greater than 1.4 and, more preferably, greater than 1.6; and, furthermore, the colorant should not decompose and/or react with the molten flux when subjected to a temperature in range of from about 550 to about 1200 degrees Celsius.

Referring again to Figure 1, and the preferred embodiment depicted therein, a flux layer 22 optionally may be disposed over the ceramic colorant image element 20. Thus flux layer, when used, will be comparable to the flux layer 18 but need not necessarily utilize the same reagents and/or concentrations and/or coating weight.

Disposed over the colorant image element 20, and coated either onto such element 20 or the optional flux layer 22, is a flux covercoat 24. Covercoats are described in the patent art. See, e.g., United States patents 6,123,794 (covercoat used in decal), 6,110,632, 5,912,064, 5,779,784 (Johnson Matthey OPL 164 covercoat composition), 5,779,784, 5,601,675 (screen printed organic covercoat), 5,328,535 (covercoat for decal), 5,229,201, and the like. The disclosure of each of these United States patents is hereby incorporated by reference into this specification.

The covercoat 24, in combination with the other flux-containing layers, must provide sufficient flux so that the ratio of flux to colorant is within the specified range. Furthermore, it must apply structural integrity to the ceramic colorant image element 20 so that, as described elsewhere in this specification, when composite 10 is removed from its backing material, it will retain its structural integrity until it is applied to the ceramic substrate.

For water slide image transfer processes, the covercoat 24 should be substantially water-insoluble so that, after it is contacted with water at 40 degrees Celsius for 1 minute, less than 0.5 percent will dissolve. For heat and adhesive transfer processes, the covercoat need not be water insoluble.

For water slide image transfer processes the covercoat 24 should preferably have an elongation before break, as measured by standard A.S.T.M. Test D638-58T, of more than 5 percent. For heat and adhesive transfer processes, where the imaged covercoat is never unsupported, the covercoat elongation before break may vary over a broad range, so long as the covercoat can be cleanly separated from the decal with no appreciable distortion of the image.

The covercoat 24 should be applied at a sufficient coating weight to result in a coating weight of at least 2 grams per square meter and, more preferably, at least 5 grams per square meter.

The covercoat 24 preferably is comprised of the aforementioned flux and carbonaceous material(s) which, in one preferred embodiment, when subjected to a temperature of 440 degrees Celsius for at least 5 minutes, will be substantially completely converted to gaseous material. In another embodiment, when covercoat 24 is subjected to a temperature of at least about 500 degrees Celsius for at least 10 minutes, will be substantially completely converted to gaseous material. The aforementioned binders, and/or waxes, and/or plasticizers described, e.g., with relation to layers 14, 16, 18, 20, 22, and 24, are suitable carbonaceous materials, and one or more of them may be used in the proportions described with regard to layer 14 to constitute the covercoat.

One may use a covercoat 24, which is similar in composition and structure to the layer 14. In one embodiment, it is preferred that the covercoat 24 be comprised of a binder selected from the group consisting of polyacrylate binders, polymethacrylate binders, polyacetal binders, mixtures thereof, and the like.

Some suitable polyacrylate binders include polybutylacrylate, polyethyl-cobutylacrylate, poly-2-ethylhexylacrylate, and the like.

Some suitable polymethacrylate binders include, e.g., polymethylmethacrylate, polymethylmethacrylate- co-butylacrylate, polybutylmethacrylate, and the like.

Some suitable polyacetal binders include, e.g., polyvinylacetal, polyvinylbutyral, polyvinylformal, polyvinylacetal-co-butyral, and the like.

Covercoat 24 preferably should have a softening point in the range of from about 50 to about 150 degrees Celsius.

In one embodiment, covercoat 24 is comprised of from 0 to 75 weight percent of frit and from 25 to about 100 weight percent of a material selected from the group consisting of binder, wax, plasticizer and mixtures thereof.

Figure 2 is a schematic representation of a preferred ribbon which may be used in the process of this invention. Referring to Figure 2, it will be seen that ribbon 30 is comprised of a flexible substrate 32.

Substrate 32 may be any substrate typically used in thermal transfer ribbons such as, e.g., the substrates described in United States patent 5,776,280; the entire disclosure of this patent is hereby incorporated by reference into this specification. In one embodiment, substrate 32 is a flexible material which comprises a smooth, tissue-type paper such as, e.g., 30-40 gauge capacitor tissue. In another embodiment, substrate 32 is a flexible material consisting essentially of synthetic polymeric material, such as poly(ethylene terephthalate) polyester with a thickness of from about 1.5 to about 15 microns which, preferably, is biaxially oriented. Thus, by way of illustration and not limitation, one may use polyester film supplied by the Toray Plastics of America (of 50 Belvere Avenue, North Kingstown, Rhode Island) as catalog number F53.

By way of further illustration, substrate 32 may be any of the substrate films disclosed in United States patent 5,665,472, the entire disclosure of which is hereby incorporated by reference into this specification. Thus, e.g., one may use films of plastic such as polyester, polypropylene, cellophane, polycarbonate, cellulose acetate, polyethylene, polyvinyl chloride, polystyrene, nylon, polyimide, polyvinylidene chloride,

polyvinyl alcohol, fluororesin, chlorinated resin, ionomer, paper such as condenser paper and paraffin paper, nonwoven fabric, and laminates of these materials.

Affixed to the bottom surface of substrate 32 is backcoating layer 34, which is similar in function to the "backside layer" described at columns 2-3 of United States patent 5,665,472. The function of this backcoating layer 34 is to prevent blocking between a thermal backing sheet and a thermal head and, simultaneously, to improve the slip property of the thermal backing sheet.

Backcoating layer 34, and the other layers which four the ribbons of this invention, may be applied by conventional coating means. Thus, by way of illustration and not limitation, one may use one or more of the coating processes described in United States patents 6,071,585 (spray coating, roller coating, gravure, or application with a kiss roll, air knife, or doctor blade, such as a Meyer rod), 5,981,058 (myer rod coating), 5,997,227, 5,965,244, 5,891,294, 5,716,717, 5,672,428, 5,573,693, 4,304,700, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

Thus, e.g., backcoating layer 34 maybe formed by dissolving or dispersing the above binder resin containing additive (such as a slip agent, surfactant, inorganic particles, organic particles, etc.) in a suitable solvent to prepare a coating liquid. Coating the coating liquid by means of conventional coating devices (such as Gravure coater or a wire bar) may then occur, after which the coating may be dried.

One may form a backcoating layer 34 of a binder resin with additives such as, e.g., a slip agent, a surfactant, inorganic particles, organic particles, etc.

Binder resins usable in the layer 34 include, e.g., cellulosic resins such as ethyl cellulose, hydroxyethylcellulose, hydroxypropylcellulose, methylcellulose, cellulose acetate, cellulose acetate butyrate, and nitrocellulose. Vinyl resins, such as polyvinylalcohol, polyvinylacetate, polyvinylbutyral, polyvinylacetal, and polyvinylpyrrolidone also may be used. One also may use acrylic resins such as polyacrylamide, polyacrylonitrile-co-styrene, polymethylmethacrylate, and the like. One may also use polyester resins, silicone-modified or fluorine-modified urethane resins, and the like.

In one embodiment, the binder comprises a cross-linked resin. In this case, a resin having several reactive groups, for example, hydroxyl groups, is used in combination with a crosslinking agent, such as a polyisocyanate.

In one embodiment, a backcoating layer 34 is prepared and applied at a coat weight of 0.05 grams per square meter. This backcoating 34 preferably is polydimethylsiloxane urethane copolymer sold as ASP-2200@ by the Advanced Polymer Company of New Jersey. One may apply backcoating 34 at a coating weight of from about 0.01 to about 2 grams per square meter, with a range of from about 0.02 to about 0.4 grams/square meter being preferred in one embodiment and a range of from about 0.5 to about 1.5 grams per square meter being preferred in another embodiment.

Referring again to Figure 2, and in the preferred embodiment depicted therein, it will be seen that substrate 32 contains an optional release layer 36 coated onto its top surface of the substrate. The release layer 36, when used, facilitates the release of the ceramic colorant/binder layer 38 from substrate 32 when a thermal ribbon 30 is used to print at high temperatures.

Release layer 36 preferably has a thickness of from about 0.2 to about 2.0 microns and typically is comprised of at least about 50 weight percent of wax. Suitable waxes which may be used include carnuaba wax, rice wax, beeswax, candelilla wax, montan wax, paraffin wax, mirocrystalline waxes, synthetic waxes such as oxidized wax, ester wax, low molecular weight polyethylene wax, Fischer-Tropsch wax, and the like. These and other waxes are well known to those skilled in the art and are described, e.g., in United States patent 5,776,280.

In one embodiment, at least about 75 weight percent of layer 36 is comprised of wax. In this embodiment, the wax used is preferably carnuaba wax.

Minor amounts of other materials may be present in layer 36. Thus, one may include from about 5 to about 20 weight percent of heat-softening resin which softens at a temperature of from about 60 to about 150 degrees Celsius. Some suitable heat-softening resins include, e.g., the heat-meltable resins described in columns 2 and of United States patent 5,525,403, the entire disclosure of which is hereby incorporated by reference into this specification. In one embodiment, the heat-meltable resin used is polyethylene-co-vinyl acetate with a melt index of from about 40 to about 2500 dg. per minute.

Referring to Figure 2, and in the preferred embodiment depicted therein, the layer 36 may be omitted and the layer 38 may be directly contiguous with substrate 32.

Ceramic colorant/binder layer 38 is one of the layers used to produce the ceramic colorant image 20. In the process of the invention, a multiplicity of ribbons 30, each one of which preferably contains a ceramic colorant/binder layer 38 with different colorant(s), are digitally printed to produce said ceramic colorant image 20. What these ribbons have in common is that they all contain both binder and colorant material of the general type

and in the general ratios described for layer 20. In one preferred embodiment, there is substantially no glass frit in layer 20 (i.e., less than about 5 weight percent). The concentrations of colorant and binder, and the types of colorant and binder, need not be the same for each ribbon. What is the same, however, are the types of components in general and their ratios.

Figure 3 is a schematic representation of a preferred ribbon 40 which is similar to the ribbon 30 depicted in Figure 2 but differs therefrom in that it utilizes a flux layer 42 instead of the ceramic colorant and binder element 38. The flux layer 42, in general, has similar components, and ratios, as the composition of flux layer 18 (see Figure 1) and is used to deposit layer 14 and/or layer 18 and/or layer 22 onto the ceramic substrate 12. As will be apparent to those skilled in the art, the precise composition and coating weight of flux layer 42 will depend upon the precise composition and coating weight of the flux layer 14 and/or flux layer 18 and/or flux layer 22 desired.

In the embodiment depicted in Figure 1, at least 4 separate flux-containing layers are depicted. In general, it is preferred to utilize at least two such layers. In general, the number of layers of flux required will depend upon how much total flux must be used to keep the total flux/colorant ratio in composite 11 at least 2.0. It is preferred not to dispose all of the flux required in one layer. Furthermore, it is preferred that at least some of the flux be disposed below the ceramic colorant image, and at least some of the flux be disposed above the ceramic colorant image.

In one embodiment, at least 10 weight percent of the total amount of flux used should be disposed on top of ceramic colorant image 20 in one or more flux layers (such as layers 22 and 24). In this embodiment, at least about 50 percent of the total amount of

flux should be disposed below ceramic colorant image 20 in one or more of flux layer 18 and/or flux layer 14.

In another embodiment, from about 30 to about 70 weight percent of the entire amount of frit used in the process of this invention is disposed below the ceramic image 20, and from about 70 to about 30 weight percent of the entire amount of frit used in the process of the invention should be disposed above the ceramic image 20. As will be apparent to those skilled in the art, a layer of material which contains frit need not necessarily be contiguous with the ceramic colorant image 20 to be disposed either below or above it. Thus, by way of illustration and not limitation, and referring to Figure 1, the flux underlayer 14 is not contiguous with the ceramic colorant image 20 but is still disposed below such image.

In one embodiment, from about 40 to about 60 weight percent of the entire amount of frit used in the process of this invention is disposed below the ceramic image 20, and from about 60 to about 40 weight percent of the entire amount of frit used in the process of the invention should be disposed above the ceramic image 20. In yet another embodiment, from about 75 to about 90 weight percent of the entire amount of frit used in the process of this invention is disposed below the ceramic image 20, and from about 25 to about 10 weight percent of the entire amount of frit used in the process of the invention should be disposed above the ceramic image 20. If the required amount of flux is not disposed above the ceramic colorant image 20, applicants have discovered that poor color development occurs when cadmium pigments and other pigments are used. Inasmuch as the ceramic substrate 12 (see Figure 1) is substantially as impervious as a sintered flux layer, applicants do not know precisely why this phenomenon occurs.

For non-cadmium-containing ceramic colorant images, applicants have discovered that acceptable results utilizing a single layer of frit may be obtained so long as the single layer of frit is positioned both above the colorant image 20 and the ceramic substrate 12 and provides a ratio of total frit to ceramic colorant in excess of about 1.25, weight/weight.

Figures 4 is a schematic of yet another preferred ribbon 50 which is similar in construction to the ribbons depicted in Figures 2 and 3 but differs therefrom in containing a different arrangement of layers.

Figure 5 is a schematic of yet another preferred ribbon 52 which is similar to the ribbons depicted in Figures 2, 3, and 4 but differs therefrom in containing a flux covercoat layer 46. As will be apparent to those skilled in the art, the flux covercoat layer 46 may be used to deposit the flux covercoat 24 (see Figure 1) and, thus, should have a composition similar to the desired covercoat 24.

Figure 6 is a schematic of yet another preferred ribbon 54, which is similar to the other ribbons depicted but which, additionally, is comprised of opacification layer 48. The opacification layer 48 may be used to print opacification layer 16 (see Figure 1) and, thus, should contain substantially the same components and ratios as described for layer 16.

Figure 6A is a schematic representation of another preferred ribbon 60 of the invention which is comprised of backcoating layer 34, polyester support 32, and release layer 36. Disposed on top of release layer 36 are a multiplicity of panels which are disposed at selected locations on top of release layer 36. Using conventional printing techniques, one of such panels (such as panel 42) is first coated onto release layer 36 at

the desired location, followed by selective coating of the second panel 48, the third panel 38 etc. Although the panels 42, 48, 38, and 46 have been shown in a particular configuration in Figure 6A, it will be apparent that other panels and/or other configurations may be used.

To obtain such selective location(s) of the panels, one may a gravure coating press. What is obtained with this process is a ribbon with repeating sequences of various panels, which thus can be utilized in a single head thermal transfer printer to obtain a print image with multiple colors and or compositions and/or properties.

In this embodiment, it is preferred to use a sequence of 42/48/38/38/38/46 to obtain, with printing operation, and covercoated decal which may be used to produce an image on a ceramic substrate with good print density and good durability.

Figure 7 is a schematic representation of a ceramic decal 70, which can be produced using one or more of the ribbons depicted in Figures 2 through 6A. The various panels 38 shown in Figure 6A represent one or more ceramic colorant panels used to produce a ceramic colorant image 20.

Referring to Figure 7, and in the preferred embodiment depicted therein, the ceramic decal 70 is preferably comprised of flexible substrate 72.

Decal substrate 72 is often referred to as a "backing sheet" in the prior art; see, e.g., United States patent 5,132,165 of Blanco, the entire disclosure of which is hereby incorporated by reference into this specification. Thus, e.g., decal substrate 72 can include a dry strippable backing or a solvent mount or a water mount slide-off decal. The backing may be of paper or other suitable material such as, e.g., plastic, fabric, and the like. In one embodiment, the backing comprises paper, which is coated with a release

material, such as dextrine-coated paper. Other possible backing layers include those coated with polyethylene glycol and primary aliphatic oxyethylated alcohols.

By way of further illustration, one may use "Waterslide" paper, which is commercially available paper with a soluble gel coat; such paper may be obtained from Brittians Papers Company of England. This paper is also described in United States patents 6,110,632, 5,830,529, 5,779,784, and the like; the entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

Additionally, one may use heat transfer paper, i.e., commercially available paper with a wax coating possessing a melt point in the range of from about 65 to about 85 degrees Celsius. Such heat transfer paper is discussed, e.g., in United States patents 6,126,669, 6,123,794, 6,025,860, 5,944,931, 5,916,399, 5,824,395, 5,032,449, and the like. The disclosure of each of these United States patents is hereby incorporated by reference into this patent application.

Regardless of what backing sheet is used, it is optionally preferred that a flux layer 74 be either coated to or printed on such backing sheet 72. The thickness of such coating 74 should be at least about 5 microns after such coating has dried, and even more preferably at least about 7 microns. Applicants have discovered that when a coating weight is used which produces a thinner layer 74, poor color development results when cadmium-based ceramic colorants are used. It should be noted that, in the process described in United States patent 5,132,165, a thickness of the "prefused glass flux layer" of only from about 3 to about 4 microns is disclosed. Referring again to Figure 7, ceramic colorant images 76 (yellow), and/or 78 (magenta) and/or 80 (cyan) and/or 82 (black) may be digitally printed by sequentially using one or more ribbons 30. Flux

layers 42 may optionally be printed by utilizing ribbon 40, which can sequentially print layer 42 in between the various image colors. Alternatively, layer 42 may be printed simultaneously with the image colors by the use of ribbon 50.

The preferred ribbons depicted in Figures 2 through 6A afford one a substantial amount of flexibility, when using applicants' process, of preparing decals with many different configurations.

As will be apparent, one or more printers equipped with one or more of such ribbons can be controlled by a computer, which can produce a decal with substantially any desired combination of colors, colored patterns, images, and physical properties.

Referring again to Figure 7, the flux covercoat 46 may be printed by means, e.g., of ribbon 52.

Figure 8 is a schematic representation of a decal 80 which is similar in many respects to decal 70 (see Figure 7) but differs therefrom in containing an opacification layer 48 which is similar in function and composition to the opacification layer 48 depicted for ribbon 54 (see Figure 6); in another embodiment, not shown, the flux underlayer 14 is omitted. It should be noted that, in image 20, a multiplicity of ceramic images may be digitally printed and superimposed on each other to form such image.

Figure 9 is a flow diagram of one preferred process for preparing a ribbon of this invention. As will be apparent to those skilled in the art, the process illustrated may be used to prepare ribbon 30, and/or ribbon 40, and/or ribbon 50, etc. In step 100, one may prepare a ceramic colorant ink as described in this specification, in accordance with the description, e.g., of layer 38 of Figure 2. This ink may be used to coat the faceside of polyester support 32 in step 114 (see Figure 2).

In step 102, one may prepare a flux binder ink as described in this specification; see, e.g., layer 42 of Figure 3 and its accompanying description. This flux binder ink may be used to either directly coat the faceside of the polyester support 32 in step 112, and/or coat over an optional release layer 36 in step 110.

In step 104, a release layer is prepared as described in this specification; see, e.g., release layer 36 of Figure 2 and its accompanying description. This release layer 36 may optionally be used in step 110 to coat the face side of the polyester substrate 32.

In step 106, a backcoat ink may be prepared as described in this specification; see, e.g., backcoating layer 34 of Figure 2 and its accompanying description. This backcoat layer 34 may be used to coat the backside of the polyester substrate in step 108. In step 114, the faceside of the polyester support 32 may be coated with ceramic colorant ink.

As will be apparent to those skilled in the art, using the combination of steps illustrated in Figure 9, one may readily prepare one or more of the ribbons illustrated in Figures 2 through 5. Furthermore, although not specifically depicted in Figure 9, one may prepare an opacification layer in accordance with the description of opacification layer 48 (See Figure 6 and its accompanying description) which may be used to prepare ribbons containing such opacification layer; also see Figure 6A).

Figure 10 is a schematic diagram of a preferred process for producing a ceramic decal. In step 120, either heat transfer or Waterslide paper is provided; these papers are described in the specification (see element 72 of Figure 7 and its accompanying description). A flux and binder layer is either coated or printed on the face of such optional step 122 (see element 74 of Figure 7 and its accompanying description); and this flux and binder layer, when dried, should be at least about 7 microns thick.

In step 124, one may optionally print an opacification layer onto the flux binder layer described in step 122. This opacification layer corresponds to layer 48 of Figure 8. It is preferred, when such opacification layer is used in step 122, to print an optional flux/binder layer over the opacification layer in step 126; this optional flux binder layer is described as element 42 of Figure 8. However, as is illustrated in Figure 10, the optional flux/binder layer may be omitted, and one may proceed directly from step 124 to step 128. Alternatively, one may omit both the opacification step and the optional flux binder layer step and proceed directly from step 122 to 128.

Whichever pathway one wishes to follow, it is preferred to use a ceramic colorant thermal transfer ribbon 114 in step 128. The preparation of this ribbon was illustrated in Figure 9.

In step 128, which may optionally be repeated one or more times with different ceramic colorant ribbons 114, an color image is digitally printed using such ribbon 114 and a digital thermal transfer printer. In one embodiment, prints were produced using a Zebra 140XiII thermal transfer printer run at 4 inches per second with energy level settings ranging from 18 to 24.

The digital image to be printed is composed of one or more primary colors, and such image is evaluated to determine how many printings of one or more ceramic colorants are required to produce the desired image. Thus, in decision step 130, if another printing of the same or a different colored image is required, step 128 is repeated. If no such additional printing is required, one may then proceed to step 132 and/or step 134.

In optional step 132, an optional flux binder layer is printed over the ceramic colorant image produced in step(s) 128. This optional flux binder layer corresponds to element 42 of Figure 8. Thereafter, either one goes from step 132 to 134, or one goes directly from decision step 130 to step 134. In printing step 134, a flux covercoat corresponding to element 24 of Figure 8 is printed to complete the decal. As will be apparent to those skilled in the art, one may apply the covercoat over the entire decal (which includes both a printed image and unprinted area[s]). Alternatively, one may apply the covercoat over the entire imaged areas.

Thus, a complete decal is produced in Figure 10 and now be may be used in Figure 11 to produce the imaged ceramic article.

Figure 10A illustrates an alternative process for preparing a decal according to the invention. As will be apparent to those skilled in the art, the process illustrated in Figure 10A is very similar to the process illustrated in Figure 10 with several exceptions. In the first place, in the process of Figure 10A, in step 150 the covercoat is applied or printed to the assembly prior to the time the ceramic colorant image 128 is applied. Thereafter, following the application of ceramic colorant image 128, optional flux binder (step 126), and/or opacifying agent (step 124), and/or flux/binder (step 122) may be applied to form the decal 152.

The process of Figure 10A may be used, e.g., to print a decal, which thereafter may be applied, e.g., to a wine bottle. Thus, e.g., in such an embodiment, the image is preferably removed from the decal with hot silicone pad or a hot silicone roller. Thereafter, the image is retransferred directly onto the ceramic article (wine bottle) and processed as illustrated in Figure 11. In the process depicted in Figure 11, the decal

produced in step 134 of Figure 10 is treated in one of two ways, depending upon whether the substrate comprising the decal is Waterslide or heat transfer paper.

If the substrate comprising the image is Waterslide paper, then the decal is first soaked in hot water (at a temperature of greater than 40 degrees Celsius, for preferably at least about 30 seconds). In step 138, the image on the Waterslide paper is then separated from the paper in step 140, this image is then placed onto a ceramic substrate and smoothed to remove wrinkles or air bubbles in step 142 and dried; and the image is then "fired." The imaged ceramic substrate is subjected to a temperature of from about 550 to about 1200 degrees Celsius in step 144.

If, alternatively, the substrate is heat transfer paper, then the decal is heated above the melting point of the decal release layer on the paper in step 146; such temperature is generally from about 50 to about 150 degrees Celsius. Thereafter, while said decal release layer is still in its molten state, one may remove the ceramic colorant image from the paper in step 148, position the image onto the ceramic article in step 150, and then follow steps 142 and 144 as described hereinabove.

When one wishes to make the ornamental wine bottle referred to hereinabove, the step 148 may be accompanied with the use of the hot silicone pad and/or the hot silicone roller described hereinabove.

#### A thermal transfer ribbon comprised of frosting ink

In one preferred embodiment, the thermal transfer ribbon of this invention is used to directly or indirectly prepare a digitally printed "frost" or "frosting" on a ceramic or glass substrate. As is known to those skilled in the art, frosting is a process in which a roughened or speckled appearance is applied to metal or glass. Reference may be had,

e.g., to United States patents 6,092,942, 5,844,682, 5,585,555, 5,536,595, 5,270,012, 5,209,903, 5,076,990, 4,402,704, 4,396,393, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

Figure 12 is a schematic representation of one preferred thermal ribbon 200 comprised of a frosting ink layer 202. The ribbon depicted in this Figure is prepared in substantial accordance with the procedure described elsewhere in this specification.

The frosting ink layer 202 is preferably comprised of from about 15 to about 94.5 weight percent of a solid, volatilizable carbonaceous binder; in one preferred embodiment, the frosting ink layer is comprised of from about 20 to about 40 weight percent of such solid, volatilizable carbonaceous binder.

As used herein, the term carbonaceous refers to a material which is composed of carbon. The term volatilizable, as used in this specification, refers to a material which, after having been heated to a temperature of greater than 500 degrees Celsius for at least 10 minutes in an atmosphere containing at least about 15 volume percent of oxygen, will be transformed into gas and will leave less than about 25 weight percent (by weight of the original material) of a residue comprised of carbonaceous material.

The solid, volatilizable carbonaceous binder may be one or more of the resins, and/or waxes, and/or plasticizers described elsewhere in this specification. Reference may be had, for example, to the thermoplastic binders described elsewhere in this specification.

Referring again to Figure 12, the frosting ink layer is preferably comprised of from about 5 to about 75 weight percent of a film forming glass flux, which melts at a temperature of greater than about 550 degrees Celsius. As is known to those skilled in

the art, such a film forming material is able to form a continuous film when fired at a temperature of above 550 degrees Celsius. Reference may be had, e.g., to the frits used to form underlayer 14 (see Figure 1) and/or flux layer 18 (see Figure 1) and/or flux layer 22 (see Figure 1).

In one preferred embodiment, the frosting ink layer is comprised of from about 35 to about 75 weight percent of the film forming glass flux. In another embodiment, the frosting ink layer is comprised of from about 40 to about 75 weight percent of the film forming glass flux.

The film forming glass flux used in frosting ink layer 202 preferably has a refractive index less than about 1.4.

By way of illustration and not limitation, and in one preferred embodiment, the film forming glass flux used in frosting ink layer 202 is comprised of 48.8 weight percent of unleaded glass flux 23901 and 9.04 weight percent of OnGlaze Unleaded Flux 94C1001, each of which is described elsewhere in this specification.

Referring again to Figure 12, the frosting ink layer 12 is preferably comprised of at least about 0.5 weight percent of opacifying agent with a melting temperature of at least 50 degrees Celsius above the melting temperature of the film forming glass, a refractive index of greater than about 1.4, and a particle size distribution such that substantially all of its particles are smaller than about 20 microns. One may use one or more of the opacifying agents described elsewhere in this specification by reference to opacification layer 16 (see Figure 1). One may use other opacifying agents such as, e.g., Superpax Zircon Opacifier. This and other suitable opacifying agents are described elsewhere in this specification.

In one embodiment, from about 2 to about 25 weight percent of the opacifying agent is used. In another embodiment, from about 5 to about 20 weight percent of the opacifying agent is used. Thus, e.g., one may use 8.17 weight percent of such Superpax Zircon Opacifier opacifying agent.

In one preferred embodiment, it is preferred that the refractive index of the opacifying agent(s) used in the frosting ink layer 202 be greater than about 1.4 and, preferably, be greater than about 1.7.

The film forming glass flux(es) and the opacifying agent(s) used in the frosting ink layer 202 should be chosen so that the refractive index of the film forming glass flux material(s) and the refractive index of the opacifying agent material(s) differ from each other by at least about 0.1 and, more preferably, by at least about 0.2. In another preferred embodiment, the difference in such refractive indices is at least 0.3, with the opacifying agent having the higher refractive index.

The film forming glass flux(es) and the opacifying agent(s) used in the frosting ink layer 202 should be chosen such that melting point of the opacifying agent(s) is at least about 50 degrees Celsius higher than the melting point of the film forming glass flux(es) and, more preferably, at least about 100 degrees higher than the melting point of the film forming glass fluxes. In one embodiment, the melting point of the opacifying agent(s) is at least about 500 degrees Celsius greater than the melting point of the film forming glass flux(es). Thus, it is generally preferred that the opacifying agent(s) have a melting temperature of at least about 1,200 degrees Celsius.

It is preferred that the weight/weight ratio of opacifying agent/film forming glass flux used in the frosting ink layer 202 be no greater than about 1.25

Referring again to Figure 12, and in one embodiment, thereof, the frosting ink layer 202 is optionally comprised of from about 1 to about 25 weight percent of platy particles; in an even more preferred aspect of this embodiment, the concentration of the platy particles is from about 5 to about 15 weight percent. As is known to those skilled in the art, a platy particle is one whose length is more than three times its thickness. Reference may be had, e.g., to United States patents 6,277,903, 6,267,810, 6,153,709, 6,139,615, 6,124,031, 6,004,467, 5,830,364, 5,795,501, 5,780,154, 5,728,442, 5,693,397, 5,645,635, 5,601,916, 5,597,638, 5,560,983, 5,460,935, 5,457,628, 5,447,782, 5,437,720, 5,443,989, 5,364,828, 5,242,614, 5,231,127, 5,227,283, 5,196,131, 5,194,124, 5,153,250, 5,132,104, 4,548,801, 4,544,761, 4,465,797, 4,405,727, 4,154,899, 4,131,591, 4,125,411, 4,087,343, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

The platy particles are preferably platy inorganic particles such as, e.g., platy talc. Thus, by way of illustration and not limitation, one may use "Cantal 290" micronized platy talc sold by the Canada Talc company of Marmora Mine Road, Marmora, Ontario, Canada. This platy talc has a particle size distribution such that substantially all of its particles are smaller than about 20 microns. Alternatively, or additionally, one may use, e.g., Cantal 45-85 platy particles, and/or Sierralite 603 platy particles; Sierralite 603 particles are sold by Luzenac America, Inc. of 9000 East Nicols Avenue, Englewood, Colorado.

In one preferred embodiment, the frosting ink layer 202 optionally contains from 0.5 to about 25 weight percent of a colorant such as, e.g., the metal-oxide colorants referred to in reference to ceramic colorant layer 38 (see Figure 2). It is preferred that

such optional metal oxide pigment, when used in ink layer 202, have a refractive index of greater than 1.4.

The thermal ribbon 202 depicted in Figure 12 may be prepared by the means described elsewhere in this specification (see, e.g., the examples). In particular, the frosting ink layer 202 is preferably prepared by coating the frosting ink at a coating weight of from about 2.0 to about 15 grams per square meter onto the polyester substrate. In one embodiment, the coating weight of the frosting ink layer 202 is from about 4 to about 10 grams per square meter.

In the embodiment depicted in Figure 12, the polyester support 32 preferably has a thickness of from about 2.5 to about 15 microns, and the backcoat 34 preferably has a coating weight of from about 0.02 to about 1.0 grams per square meter. A similar ribbon 210 is depicted in Figure 13.

The ribbon 210 is substantially identical to the ribbon 200 with the exception that it contains an undercoating layer 212. This undercoat layer 212 is preferably comprised of at least about 75 weight percent of one or more of the waxes and thermoplastic binders described elsewhere in this specification, and it preferably has a coating weight of from about 0.1 to about 2.0 grams per square meter.

The ribbon 210 (see Figure 13) may be prepared by means described elsewhere in this specification. Reference may be had, e.g., to the Examples of this case.

In Figure 13 A, a ribbon 211 is illustrated which may be constructed in a manner similar to that used for ribbons 200 and 210. The ribbon 211 additionally comprises one or more covercoats 213 which are substantially free of glass frit (containing less than about 5 weight percent of glass) and which preferably each have a coating weight of from

about 1 to about 10 grams per square meter. These covercoats 213 preferably are comprised of at least 80 weight percent of one or more of the thermoplastic binders described elsewhere in this specification. In the embodiment depicted in Figure 13A, the frosting ink layer preferably has a coat weight of from about 2 to about 15 grams per square meter, the undercoat 212 preferably has a coat weight of from about 0.1 to about 2 grams per square meter, and the polyester substrate 32 preferably has a thickness of from about 3 to about 10 microns.

A similar ribbon 215 is depicted in Figure 13B. This ribbon is substantially identical to the ribbon depicted in Figure 13A with the exception that it omits a covercoat 213 disposed on top of the frosting ink layer 202.

The ribbons 200 and/or 210 and/or 211 and/or 215 may be used to prepare a frosting decal. Thus, e.g., one such process comprises the steps of applying to a water slide backing sheet a covercoat comprised of a thermoplastic material with an elongation to break greater than 2 percent and a digitally printed frosting image. The digitally printed frosting image is comprised of a solid carbonaceous binder (described elsewhere in this specification), and a mixture of a film forming glass flux and one or more opacity modifying particles, wherein the difference in the refractive index between the particles and the glass frit is at least 0.1 and the melting point of the particles is at least 50 degrees Celsius greater than that of the film forming glass flux.

The ribbons 200 and/or 210 and/or 211 and/or 215 may also be used to prepare another frosting decal. Thus, e.g., one such process comprises the steps of applying to a heat or adhesive transfer backing sheet a covercoat comprised of a thermoplastic material and a digitally printed frosting image. The digitally printed frosting image is comprised

of a solid carbonaceous binder (described elsewhere in this specification), and a mixture of a film forming glass flux and one or more opacity modifying particles, wherein the difference in the refractive index between the particles and the glass frit is at least 0.1 and the melting point of the opacity modifying particles is at least 50 degrees Celsius greater than that of the film forming glass flux.

The backing sheet used in this process may be typically polyester or paper. Alternatively, or additionally, the backing sheet may comprise or consist of cloth, flexible plastic substrates, and other substrates such as, e.g., substantially flat materials. When paper is used in this embodiment, it is preferred that it be similar in composition to the papers described elsewhere in this specification.

Figure 14 is a schematic representation of one preferred heat transfer decal 220 made with the thermal ribbon of Figure 12 or Figure 13. Referring to Figure 14, it will be seen that, in the preferred embodiment depicted, a decal release layer 304 may be coated onto flexible substrate 225 by means described elsewhere in this specification. This decal release layer 304 preferably has a thickness of from about 0.2 to about 2.0 microns and typically is comprised of at least about 50 weight percent of wax.

In one embodiment, decal release layer 304 has a surface energy of less than about 50 dynes per centimeter. Surface energy, and means for measuring it, are well known to those skilled in the art. Reference may be had, e.g., to United States patents 5,121,636 (surface energy meter), 6,225,409, 6,221,444, 6,075,965, 6,007,918, 5,777,014, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

In one embodiment, decal release layer 304 has a surface energy of less than about 40 dynes per centimeter. In another embodiment, decal release layer 304 has a surface energy of less than about 30 dynes per centimeter.

Referring again to Figure 14, a covercoat layer 224 is disposed above a paper substrate 226. The covercoat layer 224 preferably is comprised of at least 25 weight percent of one or more of the aforementioned thermoplastic materials. In one embodiment, the covercoat layer 224 is comprised of at least about 50 weight percent of such thermoplastic material.

In the preferred embodiments depicted in Figures 13, 13A, 13B, 14, 15, and 16, the covercoat layers 213 and/or 224 contain less than about 5 weight percent of glass frit. In another embodiment, such covercoat layers contain less than about 1 weight percent of glass frit.

In one preferred embodiment, the covercoat layer 224 is comprised of a thermoplastic material with an elongation to break of at least about 1 percent.

By way of illustration and not limitation, suitable thermoplastic materials which may be used in covercoat layer 224 include, e.g., polyvinylbutyral, ethyl cellulose, cellulose acetate propionate, polyvinylacetal, polymethylmethacrylate, polybutylmethacrylate, and mixtures thereof.

Referring again to Figure 14, after the covercoat layer 224 has been applied, the frosting ink image 222 may be digitally applied with the use of either the ribbon 200 and/or the ribbon 210 and/or the ribbon 211 and/or the ribbon 215 by means of the printing process described elsewhere in this specification. Figure 15 is a schematic representation of a Waterslide assembly 230 which is similar to the heat transfer paper

220 but differs therefrom in several respects. In the first place, the decal release layer 304 is replaced by the water soluble gel layer 228; in the second place, the flexible substrate 225 is replaced by the Waterslide paper substrate 229. As is known to those skilled in the art, and as is taught elsewhere in this specification, Waterslide paper is commercially available with soluble gel coating 228.

The Waterslide paper assembly (elements 229 and 228), in the embodiment depicted in Figure 15, is first coated with covercoat layer 224 with an elongation to break greater than 1%, at a coat weight of from about 2 to about 20 grams per square meter and then digitally printed with frosting ink image 222 by the means described elsewhere in this specification.

Figure 16 is a schematic representation of a transferable covercoat assembly 240, which is comprised of a flexible substrate 226, transferable covercoat 242, and frosting ink image 222.

The aforementioned description is illustrative only and that changes can be made in the ingredients and their proportions, and in the sequence of combinations and process steps, as well as in other aspects of the invention discussed herein.

Thus, for example, in one embodiment the decorated ceramic article 10 depicted in Figure 1 comprises a ceramic or glass substrate 12 on which a ceramic colorant image 20 is disposed. A similar ceramic glass substrate 301 is depicted in Figure 19. As will be apparent to those skilled in the art, in both cases the ceramic/glass substrate 12 is fired to either sinter it or to cause the materials disposed on it to adhere to it. When such firing occurs, the glass flux contained in covercoat layers 24 (Figure 19) and flux layers 14, 18 and 22 (Figure 1) melts and reforms as glass. Thus, after such firing, the ceramic

colorant image 20 of Figure 1, and the frosting ink image 222 of Figure 19, are disposed between two glass layers. Thus, e.g., Figure 19 depicts a coated ceramic/glass substrate 301, which is similar to the coated substrate assembly 10 (see Figure 1) but differs therefrom in having a covercoat 213/frosting ink image 222/covercoat layer 213 disposed over the substrate 12.

Thus, e.g., other structures may be formed in which, e.g., the frosting ink image 222 is disposed between two glass layers. By way of illustration, and in the process depicted in Figure 20, one may print a frosting ink image 222 onto a thermoplastic substrate 302 with the use of a ribbon 200, 210, 211, and/or 215. One may use a substrate such as, e.g., a sheet of biaxially oriented poly(ethylene terephthalate), a sheet of polyvinyl chloride, a sheet of polycarbonate, etc. The digitally printed thermoplastic substrate may then be attached to a first pane of ceramic or glass material and, thereafter, the assembly thus formed maybe attached to a second pane of ceramic or glass material to form a ceramic(glass)/thermoplastic sheet/ceramic(glass) laminate structure.

Figure 21 discloses a structure 305 in which the coated flexible substrate 303 is attached to a ceramic/glass substrate 12. It is preferred not to fire this structure, because the gases evolved from the flexible substrate layer 302 may degrade the frosting ink layer 305.

Figure 22 depicts a laminated structure 307 in which the assembly 303 is sandwiched between two ceramic/glass substrates 12 to fog n a laminated structure.

Figure 23 shows a structure, which is similar to that of Figure 21 but, unlike the structure of Figure 1, can not be fired without substantially degrading the structural integrity of frosting ink image 222.

A process for making a ceramic decal assembly

Figure 24 is a flow diagram of one preferred process of the invention. Referring to the process depicted in Figure 24, and in step 400 thereof, a decal is prepared which can thereafter be adhesively attached to a ceramic/glass substrate.

The decal to be prepared is preferably a digitally printed decal whose preparation is described elsewhere in this specification. One may prepare any of the ceramic decals described elsewhere in this specification.

Thus, by way of illustration, and referring to Figures 16, 25A and 25B, one may prepare ceramic decal 240 and /or ceramic decal 401 and/or ceramic decal 402. When these embodiments are used, it is preferred that they comprise a transferable covercoat 242 coated onto a flexible substrate 226 with an optional release layer 304 situated between said covercoat and said flexible substrate. One preferred aspect of this embodiment is an "ethocel coated transfer paper." This term as used herein refers to transfer paper, i.e., commercially available paper with a release coating possessing a melt point in the range of from about 65 to about 85 degrees Celsius which is coated with a layer of ethylcellulose which, in one embodiment, is about 10 grams/square meter thick. Such heat transfer paper is discussed, e.g., in United States patents 6,126,669, 6,123,794, 6,025,860, 5,944,931, 5,916,399, 5,824,395, 5,032,449, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

As will be apparent, what each of decals 240, 401 and 402 have in common is a flexible substrate 226. This flexible substrate 226, which is typically paper, is described elsewhere in the specification. However, this flexible substrate may be any type of flat,

thin, flexible sheet, for example, polyester or polyolefin films, non-woven sheets and the like. The flexible substrate for the decal may first be coated with a decal release layer and then a covercoat layer, which has also been described elsewhere in this specification. The covercoated substrate should have the characteristics of being able to receive a thermally printed digital image from the various thermal transfer ribbons described elsewhere in this specification. After printing onto such coated substrates, a ceramic decal is formed. A further characteristic of these decals is that, after the decal has been attached to the glass or ceramic substrate, the flexible substrate on which the decal was formed must be able to be cleanly separated from the image. This separation should occur between the decal release layer and the covercoat such that the covercoat and the image remain entirely on the glass and ceramic substrate.

As will also be apparent, each of the decals 401 and 402 have a decal release layer 304 in common. This decal release layer 304 preferably has a thickness of from about 0.01 to about 100 microns and a surface energy less than 50 dynes/cm. In the case of decal 240, the flexible substrate 226 preferably has a surface energy less than 50 dynes/cm.

As will also be apparent, each of the decals 240, 401 and 402 also comprise a transferable covercoat layer 242. In one embodiment, the transferable covercoat layer 242 is comprised of ethylcellulose. Such a covercoat is prepared by dissolving 12 grams of ethylcellulose with a mixture of 16.4 grams of isopropyl alcohol, 68.17 grams of toluene, and 3.42 grams of dioctyl phthalate that has been heated to 50 degrees Celsius. This solution thus formed is then applied to a wax/resin coated substrate with a Meyer rod to achieve a coating weight of about 10 grams/square meter. Thus, e.g., the

transferable covercoat layer 242 may have the same composition as covercoat layer 224 (see Figure 14) and/or covercoat layer 24. In this embodiment, covercoat layer 242 is comprised of at least about 25 weight percent of thermoplastic material with an elongation to break of greater than about 2 percent. In one embodiment, the covercoat layer 242 is comprised of at least about 50 weight percent of thermoplastic material with an elongation to break of greater than 1 percent. In each of the decals 240, 401 and 402, disposed above the transferable covercoat layer 242 is either a frosted ink image 222 (decal 240 and 401), or a ceramic colorant image 20 (decal 402). As will be apparent, what each of these image layers has in common with the other is the presence of either opacification particles or colorant particles that have a particle size distribution such that at least about 90 weight percent of such particles are within the range of from about 0.2 to about 3 microns. In addition, both of these images must be comprised of film forming glass flux. The aforementioned opacification particles or colorant particles must have a refractive index of at least about 0.1 and preferably 0.2 units different from the refractive index of the film forming glass flux used in the image. In addition, the aforementioned opacification particles or colorant particles as well as the glass flux must be non-carbonaceous in their combination and essentially inorganic such that they remain on the glass or ceramic substrate after firing. Both of these images must also have the capability to alter the visual appearance of the glass or ceramic substrates, in an image-wise fashion, after the substrates have been fired to visually reveal the intended decoration of said substrates.

In a preferred embodiment, the frosting ink image or ceramic colorant image are applied to the transferable covercoat with a digital printer. In a more preferred

embodiment, the frosting ink image or ceramic colorant image are applied to the transferable covercoat with a digital thermal transfer printer.

In another preferred embodiment, the frosting ink image or ceramic colorant image are applied to the transferable covercoat with an analog printer. In a more preferred embodiment, the frosting ink image or ceramic colorant image are applied to the transferable covercoat with a roll printing process. In a further preferred embodiment, the frosting ink image or ceramic colorant image are applied to the transferable covercoat with a gravure printing process. In another preferred embodiment, the frosting ink image or ceramic colorant image are applied to the transferable covercoat with an offset printing process. In a another preferred embodiment, the frosting ink image or ceramic colorant image are applied to the transferable covercoat with a flexo printing process.

Referring again to Figure 24, and in step 410 thereof, a pressure sensitive transfer adhesive assembly is prepared. As is indicated in Figure 26, the pressure sensitive transfer adhesive assembly is comprised of pressure sensitive transfer adhesive. These adhesives, and assemblies comprising them, are well known to those in the art. Reference may be had, e.g., to United States patents 5,319,475, 6,302,134, reissue 37,036, 6,063,589, 5,623,010, 5,059,964, 5,602,202, 6,284,338, 6,134,892, 5,931,000, and the like. Reference maybe had, e.g., to United States patent applications 20010001060A1, 20020015836A1, and the like. Reference maybe had to international patent publications EP0530267B1, EP0833965B1, EP0833866B1, WO9700922A1, W09700913A1, EP0576530B2, and the like. The entire disclosure of each of these patent publications is hereby incorporated by reference into this specification.

Pressure sensitive adhesives are also described at, e.g., pages 724-735 of Irving Skeist's "Handbook of Adhesives," Second Edition (Van Nostrand Reinhold Company, New York, New York, 1977). These adhesives are often composed of a rubbery type elastomer combined with a liquid or solid resin tackifier component.

Pressure-sensitive acrylic adhesives are often used. The acrylate pressure-sensitive adhesives are often a copolymer of a higher alkyl acrylate, such as, e.g., 2-ethylhexyl acrylate copolymerized with a small amount of a polar co-monomer. Suitable polar co-monomers include, e.g., acrylic acid, acylamide, maleic anhydride, diacetone acrylamide, and long chain alkyl acrylamides.

In one preferred embodiment, the pressure sensitive transfer adhesive is an acrylic pressure sensitive transfer adhesive. These adhesives are also well known. Reference may be had, e.g., to United States patents 5,623,010 (acrylate-containing polymer blends and methods of using), 5,605,964, 5,602,202 (methods of using acrylate-containing polymer blends), 6,134,892, 5,931,000, 5,677,376 (acrylate-containing polymer blends), 5,657,516, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

One suitable pressure sensitive transfer adhesive assembly is sold as "Arclad 7418" by Adhesives Research, Inc. of 400 Seaks Run Road, Glen Rock, Pennsylvania. This assembly is comprised of an acrylic adhesive and a densified kraft liner. Other laminating adhesive assemblies also may be used in the process of this invention. Reference may be had, e.g., to United States patents 5,928,783 (pressure sensitive adhesive compositions), 5,487,338, 5,339,737, and the like. Reference may also be had

to European patent publications EP0942003A1, EP0684133B1, EP0576128A1, and the like.

Applicants have unexpectedly found that certain non-acrylate based pressure sensitive adhesives may greatly disrupt the frosting or ceramic colorant image during the firing step 460 of the process depicted in Figure 24. Not wishing to be bound to any particular theory, applicants believe that certain non-acrylate based adhesives may vigorously decompose in firing step 460. Such vigorous decomposition of the adhesive, situated between the glass or ceramic substrate and the frosting or ceramic colorant image, would likely be able to disrupt the integrity of such an image, substantially changing its original character and associated optical characteristics.

Referring again to Figure 26, and in the preferred embodiment depicted therein, the pressure sensitive adhesive assembly 410 is comprised of pressure sensitive adhesive 412, silicone release coating 413, transfer substrate 414, and silicone release coating, 415. The adhesive assembly 410 preferably has a thickness 416 of less than about 500 microns, preferably being from about + 25 to about 200 microns thick. More preferably, the adhesive assembly 410 has a thickness 416 from about 0.1 50 to about 2 100 microns thick.

Referring again to Figure 26, and in the preferred embodiment depicted therein, the pressure sensitive adhesive assembly 410 is comprised of pressure sensitive adhesive 412. The pressure sensitive adhesive 412 has a thickness of less than about 100 microns, preferably being from about 0.5 to about 50 microns thick. More preferably, the pressure sensitive adhesive has a thickness from about 1 to about 25 microns thick.

In one embodiment, the pressure sensitive transfer adhesive is comprised of at least 95 weight percent of carbonaceous material and less than about 5 weight percent of inorganic material.

Referring again to Figure 24, and in step 420 of the process, the decal provided in step 400 and the pressure-sensitive transfer adhesive assembly provided in step 410 are pressure laminated to form a composite laminated structure (see Figure 27). This pressure lamination process is well known to those skilled in the art. Reference may be had, e.g., to United States patents 6,120,882, 5,866,236, 5,656,360, 5,100,181, 5,124,187, 6,270,871, 5,397,634, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

In the preferred embodiment depicted in Figure 27, the composite assembly is pressure laminated with pressure rollers 425, preferably using a light pressure of between 1 and 10 kilograms per linear centimeter. It is preferred to remove substantially all air and/or other gases between adjacent contiguous surfaces in this process.

Referring again to Figure 24, and in step 430 thereof, the release paper (comprised of the transfer substrate 414, with silicone release coatings 413/415 on its opposed surfaces) is stripped away from the pressure sensitive adhesive 412 to form a pressure-sensitive adhesive decal. This process step 430 is schematically illustrated in Figure 28.

Referring again to Figure 24, and in step 440 thereof, the pressure sensitive adhesive decal is laminated to either a glass or a ceramic substrate with light pressure (between 1 and 10 kilograms per linear centimeter) by pressure lamination; reference may be had to Figure 29, wherein this step 440 is schematically illustrated. This step 440

will leave the flexible substrate 226 and the decal release layer 304 indirectly attached to the glass or ceramic substrate 12. Alternatively, the glass or ceramic article may be directly coated or laminated with a pressure sensitive adhesive. Such an article may then be directly laminated to the decal as in Step 440, eliminating Steps 420 and 430.

Thereafter, and referring again to Figure 24, in step 450 the wax/resin coated paper or flexible substrate 226 is peeled away from the covercoat 242 of the ceramic decal assembly. The assembly that remains after this step is illustrated in Figure 31.

The assembly depicted in Figure 31 is comprised of a frosted ink image 222. As will be apparent, this will be obtained when decal 240 or 401 is used (see Figure 25A). When decal 402 is used (see Figure 25B), a ceramic colorant image 20 will be obtained.

Referring again to Figure 24, and in step 460 of the process depicted, the ceramic/glass assembly is then fired to burn off substantially all of the carbonaceous material in the assembly. In general, the assembly is subjected to a temperature of from at least about 350 degrees Celsius for at least about 5 minutes.

Thereafter, in step 470 of the process (see Figure 24), the fired substrate is measured to determine its optical quality. The optical quality of a fired substrate may be determined, e.g., by comparing the optical density of the image on the fired substrate with the optical density of the image on the unfired substrate.

Applicants process unexpectedly produces a fired product whose optical properties are substantially as good as, if not identical to, the optical properties of the unfired product.

As is illustrated in Figure 32, the unfired substrate assembly 473 is analyzed by optical analyzer 471. Thereafter, the fired substrate assembly 478 is analyzed by optical

analyzer 471. The optical properties of the fired substrate 478 are preferably at least about 80 percent as good as the optical properties of the unfired substrate 473.

In one embodiment, a pattern recognition algorithm (not shown) is used to compare the unfired image on assembly 473 to the fired image on assembly 478. The use of pattern recognition algorithms for the purpose is well known. Reference may be had, e.g., to United States patents 6,278,798 (image object recognition), 6,275,559, 6,195,475, 6,128,561, 5,024,705, 6,017,440, 5,838,758, 5,264,933, 5,047,952, 5,040,232, 5,012,522 (automated face recognition), and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

One or more matching algorithms may be used to compare these optical qualities. These algorithms, and their uses, are well known. See, e.g., United States patents 6,041,137 (handwriting definition), 5,561,475, 5,961,454, 6,130,912, 6,128,047, 5,412,449, 4,955,056 (pattern recognition system), 6,031,980, 5,471,252, 5,875,108, 5,774,357, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

In one embodiment, illustrated in Figure 32, when the substrate 12 is a clear substrate (such as, e.g., glass), one may measure and compare the transmission density of the unfired and fired optical images by means of, e.g., a densitometer. In another embodiment, illustrated in Figure 32, when the substrate 12 is an opaque substrate, one may measure and compare the reflection density of the unfired and fired optical images by means of, e.g., a densitometer. Such uses of a densitometer are well known. Reference may be had, e.g., to United States patents 3,614,241 (automatic recording densitometer which simultaneously determines and records the optical density of a strip

of photographic film), 5,525,571, 5,118,183, 5,062,714, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

Referring again to Figure 32, and in particular to fired assembly 478, it will be seen that, in the embodiment depicted, in areas 477, 479, 481, and 483 some or all of the image has been eroded during the firing. Without wishing to be bound by any particular theory, applicants believe that this erosion can occur when gases are formed during the firing and disrupt the layer 222 as they escape from the fired assembly.

Regardless of the cause of such erosion, its existence damages the optical properties of the fired substrate. The process of the instant invention produces a product in which such erosion is substantially absent.

Figure 33 is a flow diagram of another preferred process of the invention. Referring to the process depicted in Figure 33, and in step 400 thereof, which has been previously discussed in this specification, a decal is prepared which can thereafter be adhesively attached to a ceramic/glass substrate.

The decal to be prepared is preferably a digitally printed decal whose preparation is described elsewhere in this specification. One may prepare any of the ceramic decals described elsewhere in this specification.

Thus, by way of illustration, and referring to Figures 25A and 25B, one may prepare ceramic decal 401 and/or ceramic decal 402. When these embodiments are used, it is preferred that they comprise, in one preferred aspect of this embodiment, a "covercoated transfer sheet". This term as used herein refers to a flexible substrate 226 which preferably has a surface energy of less than 50 dynes per centimeter. This substrate

may be any type of flat, thin, flexible sheet, for example, polyester or polyolefin films, non-woven sheets, paper, films, sheets or foils and the like.

The flexible substrate 226 may optionally be coated with a decal release layer 304. Such decal release layer 304 preferably has a surface energy of less than 50 dyes per centimeter. Such decal release layers 304 are preferably thin coatings of silicone or fluoropolymer release agents at coating weights of 0.01 to 10 grams per square meter. Additionally, preferable decal release layers 304 may be comprised of resin coating of polyethylene, polypropylene, polybutylene and the like at coating weights from 1.0 to 100 grams per square meter.

The flexible substrate 226 and optional decal release layer 304 are then coated with a transferable covercoat 242, which has also been described elsewhere in this specification, to form a covercoated transfer sheet. The covercoated transfer sheet should have the characteristics of being able to receive a thermally printed digital image from the various thermal transfer ribbons described elsewhere in this specification. After printing onto such coated substrates, a ceramic decal 401 or 402 is formed. A further characteristic of the these decals is that, after the decal has been attached to the glass or ceramic substrate, the flexible substrate 226 on which the decal was formed must be able to be cleanly separated from the image. This separation should occur between the flexible substrate 226 and the transferable covercoat 242 such that the covercoat and the image remain entirely on the glass and ceramic substrate. Alternatively, this separation should occur between the decal release layer 304 and the transferable covercoat 242 such that the covercoat and the image remain entirely on the glass and ceramic substrate. In either case, when said transferable covercoat is printed with an image to form an imaged decal, said image has a higher adhesion to said covercoat than said covercoat has to said flexible substrate and said imaged covercoat can be separated from said flexible substrate with a peel force of less than about 200 grams per centimeter.

Covercoats are described in the patent art. See, e.g., United States patents 6,123,794 (covercoat used in decal), 6,110,632, 5,912,064, 5,779,784 (Johnson Matthey

OPL 164 covercoat composition), 5,779,784, 5,601,675 (screen printed organic covercoat), 5,328,535 (covercoat for decal), 5,229,201, and the like. The disclosure of each of these United States patents is hereby incorporated by reference into this specification.

In one embodiment, the transferable covercoat 242, in combination with the other flux-containing layers 42, provides sufficient flux so that the ratio of flux to colorant is within the specified range. Furthermore, in this embodiment, it should apply structural integrity to the ceramic colorant image so that, when it is removed from its flexible substrate, it will retain its structural integrity until it is applied to the ceramic substrate.

The transferable covercoat 242 is preferably substantially water-insoluble so that, after it is contacted with water at 40 degrees Celsius for 1 minute, less than 0.5 percent will dissolve.

The covercoat 242 should preferably have an elongation at break, as measured at 20 degrees Celsius by standard A.S.T.M. Test D638-58T, of more than 0.1 percent. As used herein, the term elongation at break refers to difference between length of the elongated covercoat and the length of the non-elongated covercoat, divided by the length of the non-elongated covercoated, expressed as a percentage.

In one embodiment, the elongation to break of the transferable covercoat 242 is greater than about 1 percent.

In one embodiment, the transferable covercoat 242 is comprised of from about 0 to about 10 weight percent of tackifying agent, by total weight of tackifying agent and covercoat binder. As used herein, the term tackifying agents includes both plasticizing agents and tackifiers. See, e.g., United States patent 5,069,954 (at column 6) wherein the use of sucrose acetate iso-butyrate is described. It is preferred not to use more than about 10 weight percent of such tackifying agent in that it has been found that over tackifying of the transferable covercoat 242 often limits the use of the covercoat in thermal transfer printing processes. The excess tackifying agent creates sufficient adhesion between the covercoated substrate and the thermal transfer ribbon that undesired pressure transfer of the ink occurs.

The transferable covercoat 242 should be applied at a sufficient coating weight to result in a coating weight of at least 1 gram per square meter and, more preferably, at

least 5 grams per square meter. In one embodiment, the covercoat 24 is applied at a coating weight of at least 10 grams per square meter.

In one embodiment, the transferable covercoat 242 preferably is comprised of the aforementioned flux and carbonaceous material(s) which, in one preferred embodiment, when subjected to a temperature of 500 degrees Celsius for at least 10 minutes, will be substantially completely converted to gaseous material. The aforementioned binders, and/or waxes, and/or plasticizers described, e.g., with relation to layers 14, 16, 18, 20, 22, and 24, are suitable carbonaceous materials, and one or more of them may be used in the proportions described with regard to layer 14 to constitute the transferable covercoat.

One may use a transferable covercoat 242 which is similar in composition and structure to the layer 14. In one embodiment, it is preferred that the transferable covercoat 242 be comprised of a binder selected from the group consisting of polyacrylate binders, polymethacrylate binders, polyacetal binders, mixtures thereof, and the like.

Some suitable polyacrylate binders include polybutylacrylate, polyethyl-co-butylacrylate, poly-2-ethylhexylacrylate, and the like.

Some suitable polymethacrylate binders include, e.g., polymethylmethacrylate, polymethylmethacrylate-co-butylacrylate, polybutylmethacrylate, and the like.

Some suitable polyacetal binders include, e.g., polyvinylacetal, polyvinylbutyral, polyvinylformal, polyvinylacetal-co-butyral, and the like.

In one embodiment, transferable covercoat 242 preferably has a softening point in the range of from about 20 to about 150 degrees Celsius.

In one embodiment, covercoat 24 is comprised of from 0 to 75 weight percent of frit and from 25 to about 100 weight percent of a material selected from the group consisting of binder, wax, plasticizer and mixtures thereof.

In each of the decals 401 and 402, disposed above the transferable covercoat layer 242 is either a frosted ink image 222 (decal 401), or a ceramic colorant image 20 (decal 402), each of which has been described elsewhere in this specification.

Referring again to Figure 33, and in step 411 thereof, a pressure sensitive transfer adhesive assembly is prepared. As is indicated in Figure 34, the pressure sensitive

transfer adhesive assembly is comprised of pressure sensitive transfer adhesive, which has been disclosed elsewhere in this specification.

Referring again to Figure 34, and in the preferred embodiment depicted therein, the pressure sensitive adhesive assembly 411 is comprised of pressure sensitive adhesive 412, adhesive release layers 416 and 418, release liner substrates 417 and 419. The pressure sensitive transfer adhesive 412 preferably has a thickness of less than about 100 microns, preferably being from about .5 to about 50 microns thick. More preferably, the adhesive 412 has a thickness from about 1 to about 25 microns.

Referring again to Figure 34, pressure sensitive transfer adhesive 412 is releasably attached on one surface to release liner 421 and on the other surface to release liner 422. Release liner 421 is comprised of release liner substrate 419 and adhesive release layer 418. Release liner 422 is comprised of release liner substrate 417 and adhesive release layer 416.

Referring again to Figure 34 the release liner substrates 417 and 419 may be either substantially the same or different. These two flexible substrates may be comprised of paper, polyester, polyethylene, polypropylene, cast or extruded films, non-woven sheets and the like and need not be comprised of the same materials. These flexible substrates 417 or 419 preferably have thicknesses in the range of 3 to 100 microns and need not be the same thickness as each other.

Referring again to Figure 34, release liner substrates 417 and 419 have adhesive release layers 416 and 418 coated on them respectively. These release layers are preferably comprised of wax, silicone release agents, fluorocarbon release agents,

polyolefin's and the like. Release layers 416 and 418 must be capable of cleanly separating from pressure sensitive transfer adhesive 412.

Release liners 421 and 422 have different levels of adhesion to the pressure sensitive transfer adhesive 412. This differential adhesion allows one release layer to be cleanly removed first, exposing one surface of the adhesive. The pressure sensitive adhesive may then be applied to the glass or ceramic substrate. Once attached to the glass or ceramic substrate, the second release liner may be removed exposing the second surface of the transfer adhesive. In a preferred embodiment, release liner 421 has lower adhesion to pressure sensitive transfer adhesive 412 than release liner 422. In this way, release liner 421 may be cleanly separated from pressure sensitive transfer adhesive 412 to expose one surface of said adhesive. Should release liners 421 and 422 have essentially the same adhesion to the pressure sensitive transfer adhesive then the adhesive would not be able to cleanly separate from one liner or the other. In such a state a portion of the pressure sensitive adhesive would stay with release liner 421 and the remainder with release liner 422. This unacceptable state is called "transfer adhesive confusion".

Preferably, the adhesion of release liner 421 to the pressure sensitive transfer adhesive 412 is about 1 to about 30 grams per centimeter. The adhesion of release liner 422 to the pressure sensitive transfer adhesive 412 is about 10 to about 50 grams per centimeter.

In one preferred embodiment the adhesion of release liner 421 to the pressure sensitive adhesive is 25.5 grams and the adhesion of release liner 422 to the pressure sensitive transfer adhesive is 32.1 grams per centimeter.

In another preferred embodiment the adhesion of release liner 421 to the pressure sensitive adhesive is 23.1 grams and the adhesion of release liner 422 to the pressure sensitive transfer adhesive is 32.9 grams per centimeter.

Preferably, in order to prevent confusion of the pressure sensitive transfer adhesive between the glass or ceramic substrate and the release liner 422, when said liner is removed from said adhesive, the adhesion of the pressure sensitive transfer adhesive to the glass or ceramic substrate must be greater than about 50 grams per centimeter.

Referring again to Figure 33, and in step 510 of the process, the release liner 421 is separated from the pressure sensitive transfer adhesive 412 to expose one surface of said adhesive. In step 520 of the process the glass or ceramic substrate 12 and the exposed surface of the pressure-sensitive transfer adhesive assembly 411 provided in step 510 are preferably laminated with a two roll nip type laminator. Preferably, a lamination pressure of between 1 and 20 kilograms per linear centimeter is used to form a composite laminated structure (see Figure 35). More preferably, a lamination pressure of between 2 and 12 kilograms per linear centimeter is used. The lamination speed is preferable between 2.5 and 50 cm per minute and more preferably between 10 and 30 cm per minute. This pressure lamination process is well known to those skilled in the art. Reference may be had, e.g., to United States patents 6,120,882, 5,866,236, 5,656,360, 5,100,181, 5,124,187, 6,270,871, 5,397,634, and the like. The entire disclosure of each of these United States patents is hereby incorporated by reference into this specification.

Referring again to Figure 33, and in step 530 of the process, the release liner 422 is removed from the pressure sensitive transfer adhesive 412, exposing its second surface (Figure 35) to form a pressure sensitive adhesive glass or ceramic substrate 423.

In the preferred embodiment depicted in Figure 36, the pressure sensitive adhesive glass or ceramic substrate 423 and the imaged decal 401 preferably laminated with a two roll nip type laminator. Preferably, a lamination pressure of between 0.5 and 10 kilograms per linear centimeter is used to form a composite laminated structure (see Figure 35). More preferably, a lamination pressure of between 1.0 and 5 kilograms per linear centimeter is used. The lamination speed is preferable between 1 and 25 cm per minute and more preferably between 2 and 15 cm per minute. It is preferred to remove substantially all air and/or other gases between adjacent contiguous surfaces in this process.

Referring again to Figure 33, and in step 540 thereof (depicted in Figure 36), the imaged decal prepared in step 400 of the process is laminated with to the pressure sensitive adhesive glass or ceramic substrate 423 from step 530 of the process (depicted in Figure 35). Subsequently, in step 550 of the process the flexible substrate 226 and decal release layer 304 are separated from the transferable covercoat 242 and frosting ink image 222 which remain adhesively attached to the pressure sensitive adhesive glass or ceramic substrate 423 to form an imaged glass or ceramic substrate assembly 474.

The assembly depicted in Figure 36 is comprised of a frosted ink image 222. As will be apparent, this will be obtained when decal 401 is used (see Figure 25A). When decal 402 is used (see Figure 25B), a ceramic colorant image 20 will be obtained.

In the preferred embodiment depicted in Figure 36, the composite assembly is pressure laminated with pressure rollers 428, preferably using pressure between 2 and 20 kilograms per linear centimeter). It is preferred to remove substantially all air and/or other gases between adjacent contiguous surfaces in this process.

Referring again to Figure 33, and in step 460 of the process depicted, the imaged ceramic/glass assembly 474 is then fired to burn off substantially all of the carbonaceous material in the assembly. In general, the assembly is subjected to a temperature of from at least about 340 degrees Celsius for at least about 5 minutes.

Thereafter, in step 470 of the process (see Figure 33), the fired substrate is measured to determine its optical quality. The optical quality of a fired substrate may be determined, e.g., by comparing the optical density of the image on the fired substrate with the optical density of the image on the unfired substrate. This process has been described elsewhere in this specification.

Figure 37 refers to a preferred embodiment in which an imaged covercoat 800 is comprised of a flexible covercoat substrate 805. In the embodiment referred to in this figure the flexible imaged transferable covercoat 800 plays a dual role of imaged transferable covercoat and flexible substrate, thereby producing a flexible imaged transferable covercoat.

Referring again to Figure 37, the flexible covercoat substrate 805 preferably is comprised of the aforementioned carbonaceous material(s) which, in one preferred embodiment, when subjected to a temperature of 440 degrees Celsius for at least 5 minutes, will be substantially completely converted to gaseous material. In another embodiment, when the flexible covercoat substrate 805 is subjected to a temperature of at least about 500 degrees Celsius for at least 10 minutes, will be substantially completely converted to gaseous material. The aforementioned binders, and/or waxes, and/or plasticizers described, e.g., with relation to layers 14, 16, 18, 20, 22, and 24, are suitable

carbonaceous materials, and one or more of them may be used in to constitute the flexible covercoat substrate 805.

Referring again to Figure 37, one may use a flexible covercoat substrate 805, which is similar in composition and structure to the layer 14. In one embodiment, it is preferred that the flexible covercoat substrate 805 be comprised of a binder selected from the group consisting of polyacrylate binders, polymethacrylate binders, polyacetal binders, cellulosics, condensation polymers, mixtures thereof, and the like.

Some suitable polyacrylate binders include polybutylacrylate, polyethyl-cobutylacrylate, poly-2-ethylhexylacrylate, and the like.

Some suitable polymethacrylate binders include, e.g., polymethylmethacrylate, polymethylmethacrylate- co-butylacrylate, polybutylmethacrylate, and the like.

Some suitable polyacetal binders include, e.g., polyvinylacetal, polyvinylbutyral, polyvinylformal, polyvinylacetal-co-butyral, and the like.

Some suitable cellulosics binders include ethyl cellulose, cellulose acetate, cellulose acetate propionate, and the like,

Some suitable condensation polymers include polybutylene adipate, polyethylene terephthalate, poly(bisphenol-A-carbonate), nylon 6,6, polyamides, polyimides polyesters, polycarbonates, polyurethanes and the like.

Referring again to Figure 37, in one embodiment, flexible covercoat substrate 805 preferably should have a softening point in the range of from about 50 to about 150 degrees Celsius.

Referring again to Figure 37, in one embodiment, flexible covercoat substrate 805 is comprised of from 0 to 75 weight percent of frit and from 25 to about 100 weight percent of a carbonaceous material.

Referring again to Figure 37, in one embodiment, flexible covercoat substrate 805 has a thickness less than 100 microns. In a preferred embodiment, flexible covercoat substrate 805 has a thickness from 0.5 to 50 microns. In a more preferred embodiment, flexible covercoat substrate 805 has a thickness from 1 to 25 microns.

Referring again to Figure 37, it should be understood by one skilled in the art that a ceramic colorant image 20 may be used in place of the frosting ink image 222, depending upon the type of image desired. Irregardless of whether the image is comprised of ceramic colorant particles or opacification particles, it is preferred that the weight/weight ratio, in the imaged covercoat substrate 805, of ceramic colorant particles or opacification particles to the film forming glass flux be no greater than about 1.25.

Referring to Figure 38, a ceramic decal assembly 820 is depicted. The ceramic decal assembly 820 is comprised of a glass or ceramic substrate 12, a layer of adhesive 810 contiguous with said substrate 12, and imaged covercoat 800 contiguous with said layer of adhesive 810. Said imaged covercoat 800 is further comprised of a flexible covercoat support 805 and a frosting ink image 222 wherein said flexible covercoat support 805 is in direct contact with said adhesive 810.

In one embodiment, the adhesive 810 is comprised of at least 95 weight percent of carbonaceous material and less than about 5 weight percent of inorganic material.

In another embodiment, adhesive 810 has a thickness of less than about 100 microns, preferably being from about 0.5 to about 50 microns thick. More preferably, the adhesive has a thickness from about 1 to about 25 microns thick.

In another embodiment, the adhesive 810 is comprised of pressure sensitive adhesive 412. In yet another embodiment, the adhesive 810 is comprised of a heat activated adhesive. In a further embodiment, the adhesive 810 is comprised of a solvent activated adhesive.

Referring again to Figure 33, the ceramic decal assembly 820 may be utilized in the firing step 460 of this process to prepare a decorated ceramic substrate 478.

Referring to Figure 39, a ceramic decal assembly 830 is depicted. The ceramic decal assembly is comprised of a glass or ceramic substrate 12, a layer of adhesive 810 contiguous with said substrate 12, and a ceramic decal 800 contiguous with said layer of adhesive 810. Said imaged covercoat 800 is further comprised of a flexible covercoat substrate 805 and a ceramic colorant image 20 wherein said image 20 is in direct contact with said adhesive 810.

Referring again to Figure 33, the ceramic decal assembly 830 may be utilized in the firing step 460 of this process to prepare a decorated ceramic substrate 478.

Referring to Figure 40, an imaged ceramic assembly 840 is formed. The imaged ceramic assembly is comprised of a glass or ceramic substrate 12, a layer of adhesive 810 contiguous with said substrate 12, and frosting ink image 222 is contiguous with said layer of adhesive 810. Said imaged ceramic assembly is formed by first attaching imaged covercoat 800 to ceramic substrate 12 with adhesive 810 to form ceramic decal assembly 845. Said frosting ink image 222 is in direct contact with said adhesive 810 in this

composite structure. The flexible covercoat substrate 805 is then peeled away from the ceramic decal assembly 845 to form the imaged ceramic assembly 840.

Referring again to Figure 40, it should be understood by one skilled in the art that a ceramic colorant image 20 may be used in place of the frosting ink image 222, depending upon the type of image desired. Irregardless of whether the image is comprised of ceramic colorant particles or opacification particles, it is preferred that the weight/weight ratio, in the image (222 or 20), of ceramic colorant particles or opacification particles to the film forming glass flux be no greater than about 1.25.

Referring again to Figure 40, the imaged ceramic assembly 840 may be utilized in the firing step 460 of this process to prepare a decorated ceramic substrate 478.

Applicant's process unexpectedly produces a fired product whose optical properties are substantially as good as, if not identical to, the optical properties of the unfired product.

The following examples are presented to illustrate the claimed invention but are not to be deemed limitative thereof. Unless otherwise specified, all parts are by weight, and all temperatures are in degrees Celsius.

#### Example 1

A frosting ink thermal transfer ribbon is prepared utilizing a 4.5 micron thick poly (ethylene terephthalate) film (Toray F31) as a substrate. The polyester film was backcoated with a polydimethylsiloxane-urethane copolymer SP2200 crosslinked with D70 toluene diisocyanate prepolymer (both of which were sold by the Advanced Polymer Company of New Jersey) at a coat weight of 0.03 grams per square meter. The

copolymer composition was applied with a Myer Rod and dried in an oven at a temperature of 50 degrees Celsius for 15 seconds.

A release coating composition was prepared for application to the face coat of the polyester film. A first mixture, mixture #1, was prepared by dissolving 3.5 grams of Therban LT 2157 ( a acrylonitrile butadiene rubber sold by The Bayer Corporation of Morristown, New Jersey) into 46.5 grams of toluene that had been heated to a temperature of 70 degrees Celsius. A second mixture, mixture #2, was then prepared by adding 12.62 grams of Polywax 850 (a polyethylene wax sold by Baker Hughes Petrolite Company of Sugarland, Texas) to 71.51 grams of toluene; the composition thus produced was mixed with 50 grams of ceramic grinding media and milled on a paint shaker for 15 minutes until substantially all of the particles were smaller than 10 microns. A third mixture, mixture #3, was prepared by heating 23.72 grams of toluene to a temperature of 70 degrees Celsius, then adding 3.78 grams of Evaflex 577 (an ethylene-vinylacetate resin sold by DuPont Mitsui and Polymers Company of Japan) until dissolved, then adding 4.62 grams of Ceramer 1608 ( a alpha-olefinic wax sold by Baker Hughes Petrolite Company of Sugarland, Texas ), then mixing until fully dissolved, and then reducing the temperature of the mixture #3 to 50 degrees Celsius. Finally, an ink was prepared by adding 23.74 grams of mixture #1 and 32.12 grams of Mixture #3 to Mixture #2. Thereafter the mixture so produced was filtered to separate the filtrate from the grinding media, and the filtrate was then coated onto the uncoated side of the polyester substrate at a coating weight of 0.75 grams per square meter using a Meyer Rod to form the release layer. The release layer coated substrate thus produced was then dried with hot air.

The polyester film, with its backcoating and release coating, then was coated with a frosted ink layer at a coating weight of 5.6 grams per square meter; the frosted ink layer was applied to the release layer. The frosted ink was prepared by mixing 60.0 grams of hot toluene (at a temperature of 60 degrees Celsius) with 14.73 grains of a mixture of Dianal BR 106 and Dianal BR 113 binders in weight/weight ratio of 1/3; these binders were purchased from the Dianal America Company of Pasadena, Texas. Thereafter, 3.99 grams of dioctyl phthalate sold by Eastman Chemical, Kingsport, TN), 48.8 grams of Unleaded Glass Flux 23901 (sold by Johnson Matthey Ceramic Inc. of Downington, Pa.) with a refractive index of 1.4, 9.04 grams of Onglaze Unleaded Glass Flux 94C1001 (sold by Johnson Matthey Ceramic Inc. of Downington, Pa) with a refractive index of 1.7, 8.17 grams of Superpax Zircon Opacifier (sold by Johnson Matthey Ceramic Inc. of Downington, Pa.) with a refractive index of 1.9, 8.17 grams of Cantal 290 (sold by Canada Talc, Marmora, Ontario, Canada), and 1.59 grams of Cerdec 1795 Black Oxide (sold by Cerdec-DMC2, Washington, Pa) were charged to the mixture. The composition thus produced was mixed with 50 grams of ceramic grinding media and milled on a paint shaker for 15 minutes until substantially all of the particles were smaller than 10 microns. Thereafter, 5.48 grams of Unilin 425 (a wax sold by the Baker Hughes Baker Petrolite Company) were dissolved in sufficient reagent grade methylethylketone to prepare a 15 percent solution, and this wax solution was then charged to the mixture with stirring, until a homogeneous mixture was obtained. Thereafter the mixture was filtered to separate the filtrate from the grinding media, and the filtrate was then coated onto the release layer of the polyester substrate at a coating weight of 5.6 grams per square meter using a Meyer Rod. The coated substrate thus produced was then dried with a hot air gun.

A covercoated backing sheet was prepared by coating a 12% solution of ethylcellulose (supplied by Dow Chemical of Midland Michigan) in toluene onto a heat transfer backing sheet (supplied by Brittains Papers, Stokes-on-Trent, United Kingdom) with a Meyer Rod to achieve a dry coating weight of 10.0 grams per square meter. The coating was dried with a hot air gun.

Thereafter a rectangular, solid fill image was printed onto the covercoated backing sheet with the frosting ribbon, prepared in this example, using a Zebra 140xi printer at an energy setting of 22 and a print speed of 10 centimeters per second to prepare a frosting ink decal.

A pressure sensitive adhesive was prepared from a 20 percent solution of an acrylic polymer, Dianal BR106 (a methyl n-butyl methacrylate copolymer, supplied by Dianal America, Pasadena, Texas) in toluene was prepared. To 100 grams of this solution was added 10 grams of dioctyl phthalate (sold by Eastman Chemical of Kingsport, Tennessee). This solution was then coated onto a glass substrate using a Meyer rod at a coatweight of 3.98 grams per square meter to form a pressure sensitive adhesive coated glass substrate.

This decal was then placed face side down onto the pressure sensitive adhesive coated glass substrate (10 centimeters x 10 centimeters x 0.5 centimeters). Pressure was applied at 1 pound per square inch to the backside of the decal for 15 seconds to affix the decal to the glass substrate. The backing sheet was then peeled away from the glass sheet, leaving the frosting ink image and associated covercoat affixed to the glass. The glass and frosting ink image were then fired in a kiln for 20 minutes at 340 degrees Celsius. This thermal treatment caused the carbonaceous binder in the frosting image to

burn away, leaving the mixture of film forming glass frit and opacifying agents on the glass sheet.

The frosting ink image was then characterized for opacity according to the Tappi Standard T519. The opacity of the unfired decal assembly was 38.23. The opacity of the fired decal assembly was 38.22, being substantially unchanged.

#### Example 2

The procedure of Example 1 was substantially followed, with the exception that the glass substrate was coated with the same acrylic pressure sensitive adhesive solution using a meyer rod to achieve a coatweight of 16.34 grams per square meter.

A decal was prepared, attached to the pressure sensitive adhesive coated glass substrate and fired essentially in the same fashion as described in Example #2. The opacity of the unfired decal assembly was 38.67. The opacity of the fired decal assembly was 38.18

#### Comparative Example 3

The procedure described in the Example 2 was substantially followed, with the exception that a non-acrylate based pressure sensitive adhesive was prepared from a 20 percent solution of a hydrogenated acrylonitrile-butadiene thermoplastic rubber, Kraton FG1924X (supplied by Shell Oil Company of Houston, Texas) in toluene.

To 100 grams of this thermoplastic rubber solution was added 10 grams of dioctyl phthalate (sold by Eastman Chemical of Kingsport, TN). This solution was then coated onto a glass substrate using a Meyer rod to achieve a coatweight of 11.48 grams per square meter. A decal was prepared, attached to the pressure sensitive adhesive coated glass substrate and fired essentially in the same fashion as described in Example #2.

The opacity of the unfired decal was 38.55. The opacity of the fired decal was 23.28. The significant loss in opacity was a direct result of voiding and the loss of etching ink image material exposing the clear glass substrate.

#### Comparative Example 4

The procedure of Example 3 was substantially followed with the exception that the pressure sensitive adhesive was coated onto the glass substrate at a higher coatweight of 16.23 grams per meter square. A decal was prepared, attached to the pressure sensitive adhesive coated glass substrate and fired essentially in the same fashion as described in Example #2. The opacity of the unfired decal assembly was 38.88. The opacity of the fired decal assembly was 24.88.

#### Example 5

The procedure of Example 1 was substantially followed with the exception that a transfer adhesive was used in place of coating the adhesive on the glass substrate. The transfer adhesive was prepared by mixing 61 grams of the UCAR 9569 acrylic emulsion (sold by the Union Carbide Corporation, a subsidiary of the Dow Chemical Company, Danbury, Connecticut) with 32 grams of UCAR 413 acrylic emulsion (sold by the Union Carbide Corporation) and 6 grams of the BYK 438 polyether modified siloxane surfactant (sold by the Byk-Chemie USA company of Wallingford, Connecticut).).

The transfer adhesive thus formed was then coated via Myer rod at a 5 grams coatweight to a 2 mil thick release liner coated with a ultraviolet-curable release coating known as UV 10 (purchased from the CPFilms company of Greenboro, Virginia). This adhesive coated liner was then laminated to a second 1 mil thick release liner coated with a platinum cured release coating known as P10 (also purchased from such CPFilms company).

A covercoat coating composition was prepared for application to the face coat of the backing sheet. The cover coat was prepared by coating Joncryl 617 (a styrene/acrylic emulsion sold by Johnson Polymers, Racine, Wisconsin) at a dry coat weight of 10 grams per square meter using a Meyer rod. The coated paper was then allowed to dry at ambient temperature for 16 hours. Thereafter a rectangular, solid fill image was printed onto the covercoated backing sheet with the frosting ribbon using a Zebra 140xi printer at an energy setting of 22 and a print speed of 10 centimeters per second to prepare a frosting ink decal.

The frosting ink decal was then affixed to a flat surface by taping the corners down such that the frosting ink image side was up. The UV 10 release liner of the adhesive was removed, and adhesive was placed adhesive side down onto the imaged transfer paper. The adhesive and paper were laminated to produce contact and remove air bubbles. The P10 release liner was then removed, and the transfer adhesive remained with the imaged decal.

The adhesive side of the decal was then positioned over the glass substrate and laminated to it as air bubbles were removed. The backing paper was then peeled away leaving the frosting ink image and cover coat on the glass.

The glass, adhesive and frosting ink image were then fired in a kiln for 10 minutes at 621 degrees Celsius. This thermal treatment caused the carbonaceous materials in the frosting ink as well as the cover coat to burn away, leaving the mixture of film forming glass fit and opacifying agents on the glass sheet. The opacifying agents remained dispersed in this film, thus rendering the film translucent yet not transparent.

The opacity of the unfired decal assembly was 38.2. The opacity of the fired decal assembly was 32.93.

#### Example 6

The procedure of Example 5 was substantially followed with the exception that the transfer adhesive was first attached to the glass substrate using a roll laminator.

A covercoat coating composition was prepared for application to the face coat of the backing sheet. The cover coat was prepared by coating Joncryl 617 (a styrene/acrylic emulsion sold by Johnson Polymers, Racine, Wisconsin) at a dry coat weight of 10 grams

per square meter using a Meyer rod. The coated paper was then allowed to dry at ambient temperature for 16 hours. Thereafter a rectangular, solid fill image was printed onto the covercoated backing sheet with the frosting ribbon using a Zebra 140xi printer at an energy setting of 22 and a print speed of 10 centimeters per second to prepare a frosting ink decal.

The UV 10 release liner of the adhesive was removed, and adhesive was placed adhesive side down onto glass substrate. The adhesive and glass substrate were laminated together with a pressure of 2.9 Kg per linear centimeter and a lamination speed of 20 cm per minute to firmly affix the two and to minimize entrapped air bubbles. The P10 release liner was then removed, exposing the second surface of the transfer adhesive. The frosting ink image side of the decal was then positioned over the adhesive laminated glass substrate and laminated with a pressure of 7.0 Kg per linear centimeter and a lamination speed of 9.0 cm per minute to it as air bubbles were removed. The flexible substrate was then peeled away, leaving the frosting ink image, cover coat and transfer adhesive on the glass.

The glass, adhesive and frosting ink image were then fired in a kiln for 10 minutes at 621 degrees Celsius. This thermal treatment caused the carbonaceous materials in the frosting ink as well as the cover coat to burn away, leaving the mixture of film forming glass fit and opacifying agents on the glass sheet. The opacifying agents remained dispersed in this film, thus rendering the film translucent yet not transparent.

The opacity of the unfired decal assembly was 38.2. The opacity of the fired decal assembly was 41.6.

It is to be understood that the aforementioned description is illustrative only and that changes can be made in the apparatus, in the ingredients and their proportions, and in the sequence of combinations and process steps, as well as in other aspects of the invention discussed herein, without departing from the scope of the invention as defined in the following claims.